

Design • Build • Program • Learn • Compete

SERVO

FOR THE ROBOT INNOVATOR

www.servomagazine.com

MAGAZINE

September 2013



Get A Little Sideways
WITH
HOLONOMIC LOCOMOTION

♦ **The Road To The
DARPA Robotics Challenge**

Can a small unfunded team compete against
the likes of NASA, JPL, and MIT?

MAKE YOUR ROBOT ROCK!



Get ready to rock with Hitec's
ultra heavy duty monster servos!

Designed with all aluminum EMI-shielded cases, knock-out steel gears and non-programmable digital circuits, the industrial strength HS-900SGS and HS-1000SGT deliver the power to make your robot a rock star!



	11.1 Volts		14.8 Volts	
	Speed	Torque	Speed	Torque
HS-900SGS	0.20 sec/60°	903 oz-in	0.15 sec/60°	1208 oz-in
HS-1000SGT	0.26 sec/60°	1167 oz-in	0.19 sec/60°	1528 oz-in
Dimensions	2.52 x 1.30 x 2.87 in		Weight	12.80 oz

For those about to ROBOT, we salute you!

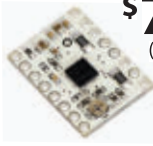




Mini Maestro 12-Channel USB Servo Controller

ITEM #1352
\$29⁹⁵

- USB, serial, and internal scripting control
- 6-, 18-, and 24-channel versions also available



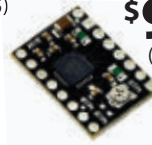
ITEM #2134
\$7⁹⁵
(qty. 5)

- DRV8834 driver
- 4-layer PCB
- Low voltage (2.5 V - 10.8 V)



ITEM #2133
\$11⁹⁵
(qty. 5)

- DRV8825 driver
- 1/32 microstepping
- 4-layer PCB



ITEM #2128
\$9⁹⁵
(qty. 5)

- A4988 driver
- 4-layer PCB



Wixel USB Wireless Module

ITEM #1337
\$19⁹⁵



Programmable MCU module featuring a 2.4 GHz radio and USB: write your own software or load precompiled, open-source apps.



Power HD High-Torque Servo 1501MG

ITEM #1057
\$19⁹⁵

- Specs at 6 V:
 - 240 oz-in
 - 0.14 sec/60°
- Metal gears and ball bearings

*High torque,
low price!*



Sanyo Pancake Stepper Motor 50x11mm

ITEM #2297
\$49⁹⁵

- Flat profile
- 1 A/phase @ 4.5 V
- 14 oz-in

*Other shapes
and sizes
available*



ACS711EX Current Sensor Carrier

ITEM #2453
\$3⁹⁵

- Hall effect-based current sensing
- Low resistance current path
- Electrical isolation up to 100 V
- Available with ± 15.5 A or ± 31 A range



Pololu Basic SPDT Relay Carrier with 12VDC Relay

ITEM #2482
\$4⁹⁵

*Dual relay
carriers
available*

Control a SPDT relay easily with a logic-level signal. Also available with a 5 V relay or without a relay.

SAVE \$10
on orders over \$50
Coupon Code:
SE092013



ITEM #1634
\$4⁴⁹



*Build a
breathalyzer!*



ITEM #1479
95¢

Indicates alcohol gas concentrations with a simple analog voltage output. Detect and measure different gases with other MQ-series gas sensors!

3pi Robot

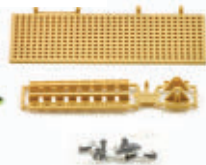
ITEM #975
\$99⁹⁵



The 3pi is a great first robot for ambitious beginners and a perfect second robot for those looking to move up from non-programmable or slower beginner robots.

Tamiya 70168 Double Gearbox Kit

ITEM #114
\$9²⁵



Tamiya 70098 Universal Plate Set

ITEM #79
\$6²⁵

Our large selection of Tamiya gearboxes and construction sets are great for building inexpensive mechanisms and robot chassis!

Universal Aluminum Mounting Hub Pair

ITEM #1203
\$7⁴⁹/pair



*Other shaft
sizes available*

Mount custom wheels and mechanisms to 5 mm motor shafts.

Pololu Wheels

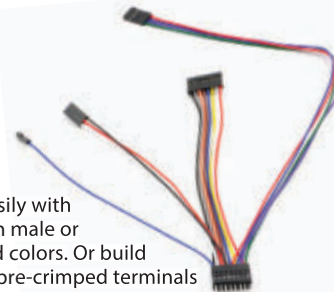
STARTING AT

\$4⁹⁸/pair



Premium Jumper Wires

STARTING AT
\$2⁹⁹/pack



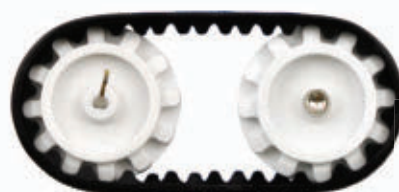
Make prototyping connections quickly and easily with these high-quality jumper wires, available with male or female terminations in a variety of lengths and colors. Or build your own custom cables using our wires with pre-crimped terminals and crimp connector housings!

22-Tooth Silicone Track Set

ITEM #1415

\$12⁹⁵

*Available with
longer tracks*



This track set includes a pair of 22-tooth silicone tracks, two drive sprockets measuring 1.38" (35 mm) in diameter, and two matching idler sprockets along with mounting hardware.

Columns

08 Robytes

by Jeff Eckert

Stimulating Robot Tidbits

- Just Think
- This is Research?
- Kibo Bot Destined for ISS
- Bot is Diggin' It

10 GeerHead

by David Geer

Modular Cooperating Robot Components

Hip, new robots from Barobo, Inc., build on themselves to form educational and prototyping platforms, as well as enable new hacks for the creative roboticist.

14 Ask Mr. Roboto

by Dennis Clark

Your Problems Solved Here

Creating autonomous behavior with Action Builder from the RoboBuilder Creative kit.

74 Then and Now

by Tom Carroll

Parallax, Inc.

Learn about the beginnings of this ground-breaking company and some of the products they're famous for.

The Combat Zone...

28 BUILD REPORT:

Tanto

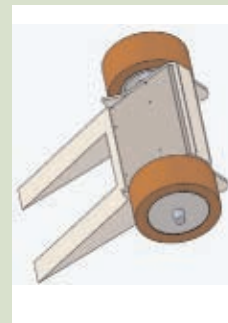
31 THEN and NOW:

A Decade Later With Richard Stuplich

33 Orangutan Drives Fleaweight

34 PRODUCT REVIEW:

Botbitz 30A ESCs



Departments

06 Mind/Iron
It's Good to be Flexible

20 Events
Calendar

21 Showcase

22 New Products

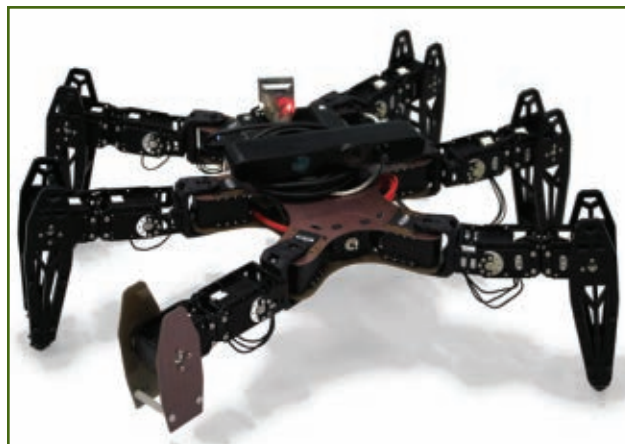
62 SERVO
Webstore

81 Robo-Links

81 Advertiser's
Index

24 Bots in Brief

- Curiosity Turns One
- You've Got Gas
- Attack of the Giant Crab
- Winging It
- High-Stepping HyQ
- Headed for Trouble
- Leaping Lovers
- Warrior Suit
- Great Gait!
- Whegs Gone Wild



36 3D Printers Part 5: Filament

by Michael Simpson

Filament is the life blood of a 3D printer.

This month, various types of filament are discussed and how to calibrate the printer for a specific kind.

44 A Look at Holonomic Locomotion

by Roger Tang and Dick Swan

Holonomic robots are omnidirectional and incredibly mobile. This article looks at these types of robots constructed with two different styles of wheels.

50 Making Better Arduino Robots with the ArdBot — Part 2

by Gordon McComb

We'll move forward with completing the ArdBot II's electrical subsystems, and give our robot its first taste of adventure with a simple servo test routine.

58 The Road to the DARPA Robotics Challenge

by Daniel Albert and Chris Mayer

Read one team's chronicle of what it will take to compete in track D of this monumental event.

67 The Fourth Annual Lunabotics Competition

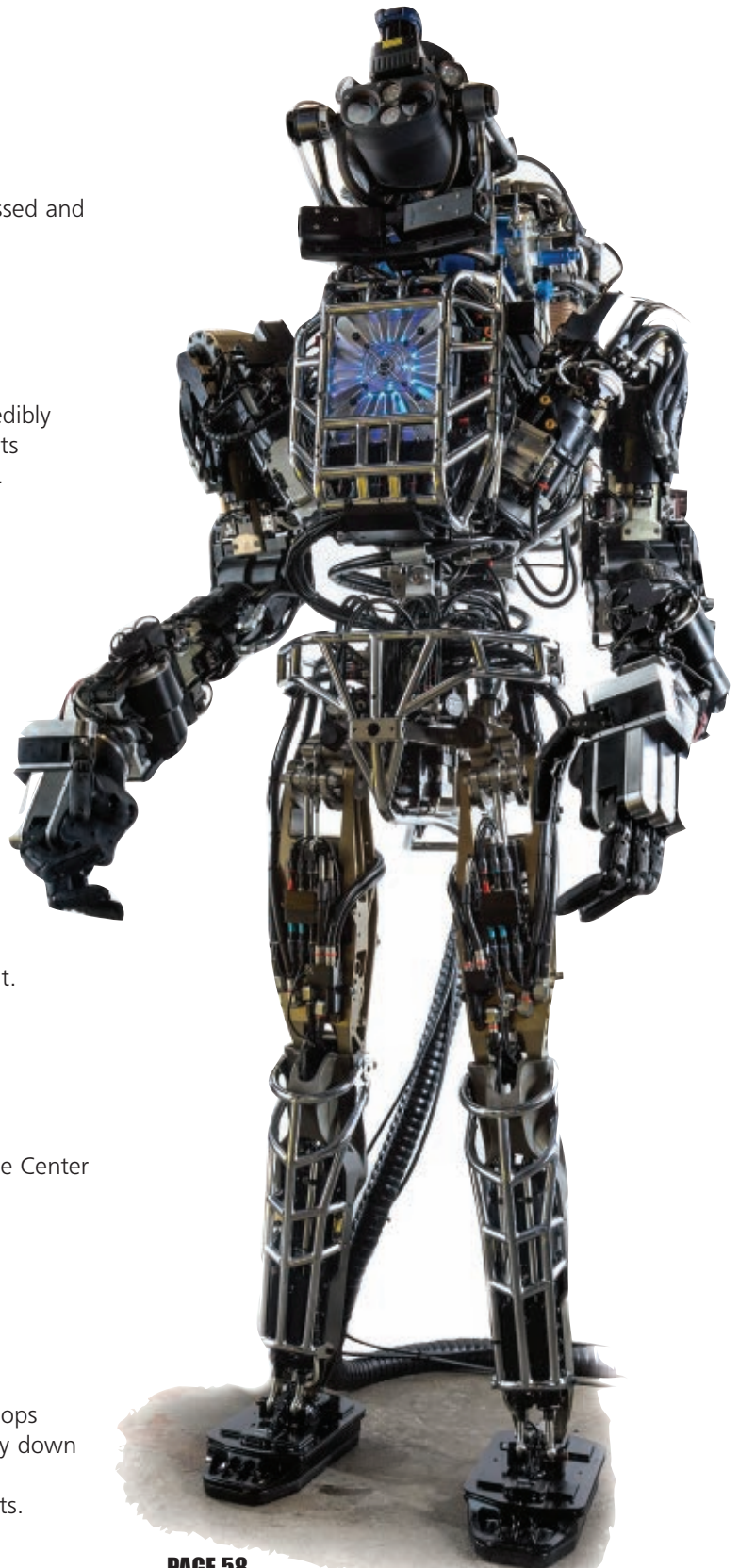
by Morgan Berry

College students descend on the Kennedy Space Center for NASA's yearly contest to build lunar rovers.

71 LEGO Mindstorm Robots at the 2013 Lunabotics Competition

by Morgan Berry

As part of NASA's annual event, special workshops were held for school-aged children — all the way down to preschool — to help foster a love for STEM education by learning to use LEGOs to build bots.



PAGE 58

It's Good to be Flexible

Soft, squishy robot prototypes — often based on microfluidics networks — have been around academic labs a while. You can imagine the applications of a rescue robot that can squeeze through cracks to get to the injured, or a military robot that can ooze under a door to deliver a toxic gas or other payload. While both scenarios are still in the realm of sci-fi, there continues to be significant progress in the development of practical flexible robots and flexible components.

On the almost practical front, you've probably seen the flexible 3D printed dress created with a new, flexible material from Materialise (materialise.com). In the long-term, truly custom clothes might be a mouse-click away. In the nearer term, flexible 3D printing could be a game changer for the experimentalist — especially in the form of flexible circuit boards.

You've no doubt encountered flexible boards and flat ribbon connectors in some cameras. I have yet to see those flexible Li-Ion batteries for sale in quantities less than a few thousand pieces, but flexible solar panels, light panels, and conductive plastic sheet are available off the shelf. For example, I'm having fun working with flexible — but not foldable — electroluminescent (EL) panels, ribbons, and wires available from Adafruit and SparkFun. It's odd being able to trim the active area of the plastic-phosphor material with a pair of scissors without harming the light output.

I'm also working with transparent conductive plastic sheets available from Adafruit. Although the indium tin oxide coating doesn't accept solder, it does work with conductive adhesives, pens, and paints to attach components. It's also possible to scrape away the coating to create flexible circuit board tracings.

Of course, if you're a fan of wearable computing, you've no doubt worked with one of the wearable Arduino-compatible boards such as FLORA from Adafruit and the LilyPad from SparkFun. While the button-sized boards are stiff conventional boards, they connect with the outside world through metal-infused thread that's as flexible as ordinary cotton.

Need a string of LEDs that bend and flex as you do? No problem. Just use conductive cloth, ribbons, or thread to hook up your wearable flexible circuit. SparkFun also sells a fabric kit that uses conductive fabric ribbon to connect wearable LED modules for making billboard-style jackets and shirts. The conductive thread — like the modules — is supposedly immune to hand washing, but I haven't put the claims to the test.

Flexibility seems poised to make a dent in the consumer electronics world, as well. There are persistent rumors of curved screen cell phones that can survive being sat on. Then there's the curved face of the rumored Apple's 'Dick Tracy' watch. Flexible displays made of materials (such as Corning's Willow) are paving the way for flexible consumer devices. The benefit of these and other technologies to robotics will undoubtedly be a wealth of affordable flexible components that will enable anyone to experiment with flexible platform designs. **SV**

Published Monthly By

T & L Publications, Inc.

430 Princland Ct., Corona, CA 92879-1300

(951) 371-8497

FAX **(951) 371-3052**

Webstore Only **1-800-783-4624**

www.servomagazine.com

Subscriptions

Toll Free **1-877-525-2539**

Outside US **1-818-487-4545**

P.O. Box 15277, N. Hollywood, CA 91615

PUBLISHER

Larry Lemieux

publisher@servomagazine.com

**ASSOCIATE PUBLISHER/
VP OF SALES/MARKETING**

Robin Lemieux

display@servomagazine.com

EDITOR

Bryan Bergeron

techedit-servo@yahoo.com

CONTRIBUTING EDITORS

Jeff Eckert

Tom Carroll

Dennis Clark

Michael Simpson

Dick Swan

Daniel Albert

Morgan Berry

Zachary Witeof

Jenn Eckert

Kevin Berry

R. Steven Rainwater

Gordon McComb

Roger Tang

Chris Mayer

Craig Danby

David Geer

CIRCULATION DEPARTMENT

subscribe@servomagazine.com

MARKETING COORDINATOR

WEBSTORE

Brian Kirkpatrick

sales@servomagazine.com

WEB CONTENT

Michael Kaudze

website@servomagazine.com

ADMINISTRATIVE ASSISTANT

Debbie Stauffacher

PRODUCTION

Sean Lemieux

Copyright 2013 by

T & L Publications, Inc.

All Rights Reserved

All advertising is subject to publisher's approval. We are not responsible for mistakes, misprints, or typographical errors. *SERVO Magazine* assumes no responsibility for the availability or condition of advertised items or for the honesty of the advertiser. The publisher makes no claims for the legality of any item advertised in *SERVO*. This is the sole responsibility of the advertiser. Advertisers and their agencies agree to indemnify and protect the publisher from any and all claims, action, or expense arising from advertising placed in *SERVO*. Please send all editorial correspondence, UPS, overnight mail, and artwork to: **430 Princland Court, Corona, CA 92879.**

Printed in the USA on SFI & FSC stock.



Shop Online
Call 620-221-0123
sales@servocity.com

Actobotics™
BALL-BEARING PRECISION BUILDING SYSTEM

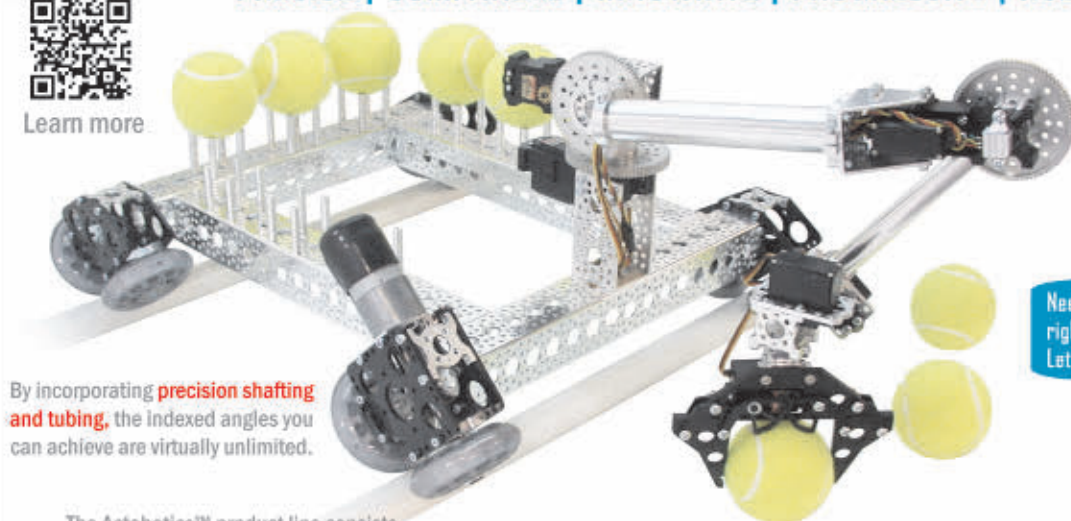
**DREAM.
DESIGN.
BUILD.
REPEAT.**

#IN WITH THE NEW

PRECISE | COMPATIBLE | INNOVATIVE | PROGRESSIVE | ROBUST | MOBILE | INTUITIVE



Learn more



By incorporating **precision shafting and tubing**, the indexed angles you can achieve are virtually unlimited.

The Actobotics™ product line consists of **hundreds of individual components** and continues to expand at a rapid rate.

Standardized sizing allows the use of non-Actobotics components including servos, motors, actuators, and R/C vehicle components.

Our new line of precision components will **change the way you build robotic structures forever** - experiment, disassemble, and rebuild structures faster than ever before!

Need help choosing the right parts for your project?
Let us help! tech@servocity.com

ARE YOU A DIY ENTHUSIAST?

WE HAVE THE PARTS FOR YOUR IDEAS

- ✓ Servos & Accessories
- ✓ Motors & Accessories
- ✓ Servo Controllers
- ✓ Motor Controllers
- ✓ Transmitters & Accessories
- ✓ Pan/Tilt/Roll & Accessories
- ✓ Camera Accessories
- ✓ Robots & Accessories
- ✓ Channel & Brackets
- ✓ Shafting & Tubing
- ✓ Hubs, Couplers & Adaptors
- ✓ Bearings & Bushings
- ✓ Gears
- ✓ Sprockets & Chain
- ✓ Pulleys & Belts
- ✓ Wheels & Tires
- ✓ Fasteners & Hardware
- ✓ Batteries & Power Supplies
- ✓ Wire/Connectors & Access.
- ✓ Electronics & Accessories
- ✓ Tools

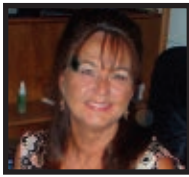


WORLDWIDE SHIPPING!

www.SERVOCITY.com

JOIN OUR ONLINE COMMUNITY!





Robytes

by Jeff and Jenn Eckert

Just Think

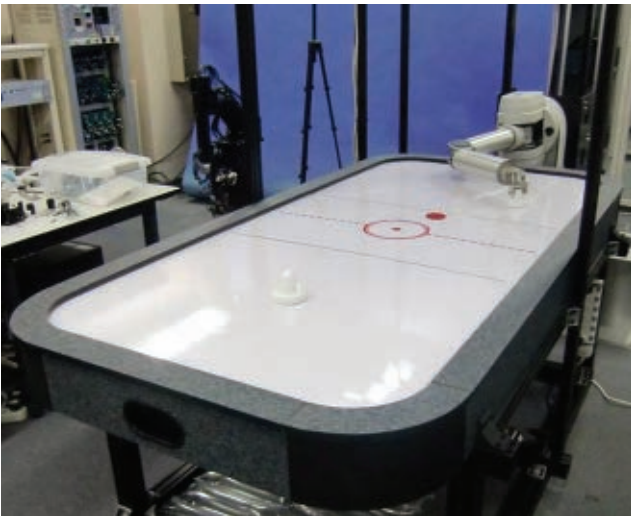
Back in 1994, a concerned citizen wrote to the L.A. Police Department and claimed that — if they would allow it — he could connect a slew of electromagnetic sensors to the brain of O.J. Simpson's dog and thus obtain its testimony in the murder case. Presumably, he was put away somewhere for his own safety, but researchers at the University of Minnesota's College of Science and Engineering (cse.umn.edu) have accomplished pretty much the same thing — minus Fido.

By strapping a skullcap fitted with 64 electrodes onto some of his students, Prof. Bin He enabled them to deftly control the movements of a quadcopter using only their thoughts. During the tests, the subjects faced away from the UAV and imagined using their hands to make it turn right, turn left, rise, and fall. Their brainwaves were relayed to the 'copter via Wi-Fi, and they tracked its motion on a screen that displayed images from an onboard camera. After a few training sessions, each student was able to navigate through large rings suspended from the ceiling.



Mind-controlled UAV navigates through garlands of balloons.

This isn't all fun and games, however. According to Karl LaFleur, a senior engineering student and one of the participants, "Our next step is to use the mapping and engineering technology we've developed to help disabled patients interact with the world. It may even help patients with conditions like autism or Alzheimer's disease, or help stroke victims recover. We're now studying some stroke patients to see if it'll help rewire brain circuits to bypass damaged areas."



Robotic player anticipates its opponent's moves.

This is Research?

You have to admire academic's creative use of language. For example, who would suspect that when researchers at Chiba University's Namiki Lab (mec2.tm.chiba-u.jp) set out "to develop the technology of a high speed human-interactive robot in which the robot reads the opponent's intention and moves in response to the opponent's motion and human purpose expectation," they were really just programming a Barrett four-axis arm to play air hockey. Robots have already been doing that for years.

For example, a YouTube video from back in 2006 shows a Sarcoman unit doing the same thing. The difference, however, is that this one "is able to strategize playing against its human opponent" and shift its strategy based on how the opponent plays. Cool.

The obvious next step is to supplement the robotic strategic dynamism with algorithms to optimize the human implementation of malted grain-derived potables (i.e., teach the robot to bring me a beer.)

Kibo Bot Destined for ISS

Apparently, the Japanese have become so attached to their humanoid robots that they can't even travel into outer space without one. So, when Japanese Aerospace Exploration Agency (JAXA) astronaut Koichi Wakata takes command of the International Space Station next March, he will find a mechanical companion awaiting him. The android — produced by Japan's Kibo Robot Project — will be programmed to recognize Wakata and communicate with him in Japanese. The bot won't take up much room since it's only 34 cm (13.4 inches) tall and weighs only 1 kg (2.2 lb). It will also take photos and relay lab data back to Earth.

As of this writing, no one has come up with a name for the little guy or his twin who will remain on Earth to do public relations work. Fortunately, you can visit kibo-robot.jp for updates.

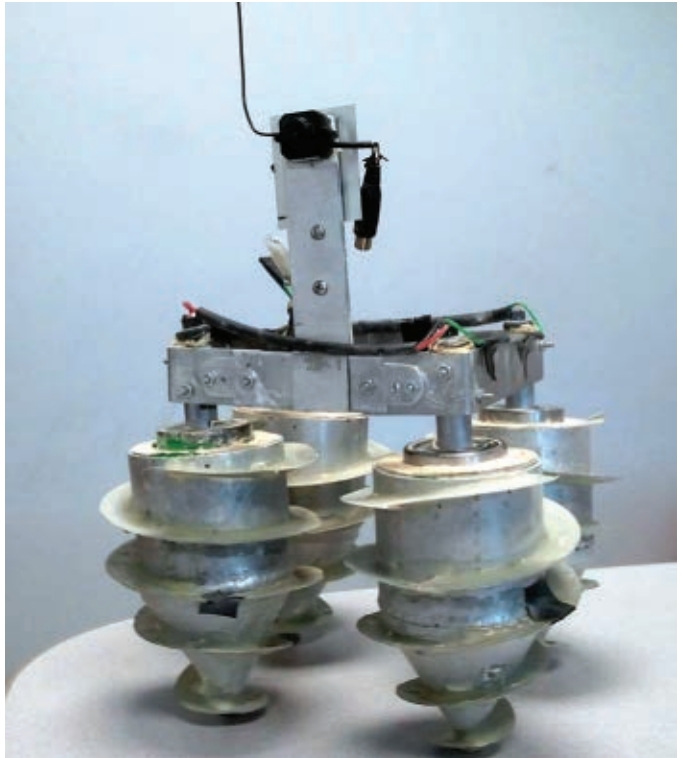


Miniature android is set to serve in Expedition 39 aboard the ISS.

Bot is Diggin' It

Although there is no shortage of bots designed to travel over land, air, and sea, most subterranean explorations require human participation. At the 2013 IEEE International Conference on Robotics and Automation, some folks from the Carnegie Mellon Robotics Institute (www.ri.cmu.edu) presented a paper describing a bimodal unit that is capable of rolling along the surface to reach its destination, then screwing itself into the ground when it arrives. According to the paper, "The applications of a self-burying robot extend from mining and military applications to humanitarian applications." Or, more specifically, "to drive or be air-dropped to a location close to a target, bury itself to be hidden, perform video surveillance, and send that video back to an operator."

The basic function is to dig straight down into a layer of sand or other material until the entire frame is covered. Servo motors inside the four drills cause the metal cylinder and cone to rotate, and the thin "grousers" slice through the material and force it upward. The paper indicates that the unit has been tested in homogeneous substances including sand, rice, sugar, and flour, but it isn't clear how it would handle real dirt. Nevertheless, the authors surmise that in the future, "many other interesting applications like covert surveillance and autonomous exploration can be achieved with this platform." **SV**



Self-burying mechanical mole from Carnegie Mellon Robotics.



GEERHEAD

by David Geer

Contact the author at geercom@windstream.net

Modular Cooperating Robot Components

The Linkbot platform from Barobo, Inc., applies a sort of swarm robotics to individual modules that can be easily connected, expanded, programmed, and controlled. The idea is to encourage young children to become interested in robotics early on to help fill the gap where interest in robots in education is declining. Read on to find out what Linkbots are made of, as well as how they work and what they can do.

Linkbot Parts, Technologies, and Proprietary Capabilities

Linkbot is a modular robotics platform that consists of like components you can connect or link together to form higher order robots. The components come with a number of built-in capabilities, including a 802.15.4-compliant ZigBee-capable wireless radio transceiver operating in the 2.4 GHz band. Roboticists can use this to communicate wirelessly, create mesh networks, and control and monitor Linkbots remotely. Linkbots also include a rechargeable lithium-ion battery good for three hours of run time; a three-axis accelerometer for detecting free falls, bumps, and tilt angles; absolute encoding; compatibility with Arduinos; and ease of hacking.

As mentioned, the Linkbot's internal chip is Arduino-compatible (the Leonardo). The ATmega128RFA1 by Atmel runs at 16 MHz. This integrates with an eight-bit AVR microcontroller. Builders can re-Flash with their own firmware using the onboard boot loader.

There are also Arduino-compatible breakout boards and accessory boards that are available, so users can add sensors or add the Linkbot into their existing projects. Expansion boards plug into the robot, enabling the roboticist to connect several devices such as IR proximity sensors, buttons, and switches, photo detectors, and more LEDs.

You can use a phone cable to connect the Bluetooth-

enabled breakout boards or electronics to Linkbot power. It uses a standard phone jack (you would find at any hardware store) which has four lines: two power and two I²C communication. Barobo set it up so a Linkbot outputs 5V on the breakout board, so you can power your attachments off the built-in lithium-ion battery. Bluetooth 2.0 enables the Linkbots with direct wireless communication with computers and mobile devices such as Android phones and tablets.

Linkbot uses Arduino Xbee and accelerometers, as well. There's also a buzzer capable of playing multiple notes and tunes to give audio responses to various inputs. Linkbot's BaroboLink Software uses a graphical user interface (GUI) to run programs, actuate motors, and read sensors. The robot's polycarbonate housing is very durable and has been drop-tested from second story buildings (Barobo does

3D Models

Barobo grants roboticists access to all the 3D models for the accessories, so they can print them out using most any 3D hobby grade printer. "We want to build a community where you can download parts, make them uniquely yours, and upload them to share with other roboticists. We have created some cool ideas for accessories but we are only scratching the surface, and we need your help and genius to further these," says President Graham Ryland.

Discuss this topic at <http://forum.servomagazine.com>.

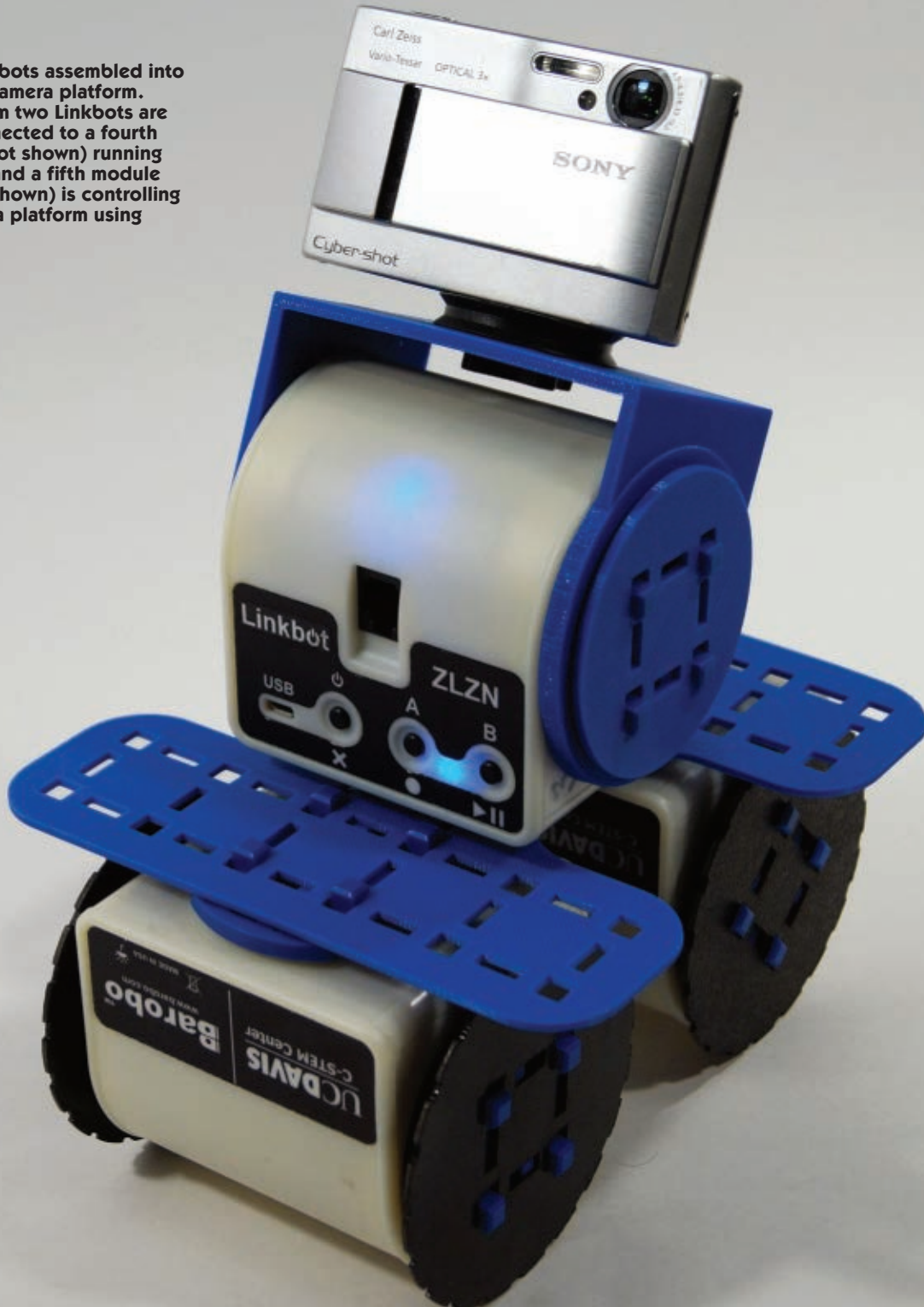
not recommend this to users).

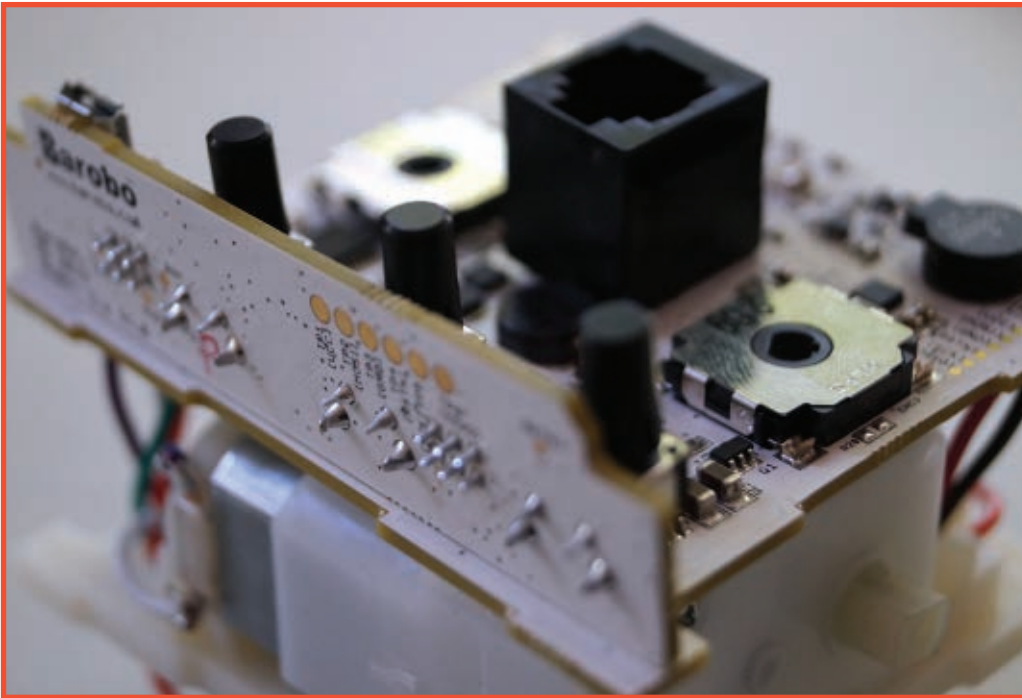
The robot comes with a proprietary TiltDrive technology that enables the user to drive a Linkbot via either a smartphone equipped with an accelerometer or another

Linkbot, which also functions as a remote control.

Once a Linkbot is BumpConnected to one or more other modules, the built-in TiltDrive mode allows the user to tilt a module forward, back, left, and right to drive

Three Linkbots assembled into a mobile camera platform. The bottom two Linkbots are BumpConnected to a fourth module (not shown) running TiltDrive, and a fifth module (also not shown) is controlling the camera platform using CopyCat.





The internal electronics board of the Linkbot modular robot with motors and button board.

the robot around.

Linkbot's CopyCat technology enables builders to use the same smartphone (or another Linkbot) to control the motors in another Linkbot (motors have a high torque-to-

weight ratio, are light but strong, and produce up to 100 oz torque). CopyCat takes the rotations you make on one Linkbot and drives the other modules to copy it.

This is cool when you want to quickly make a robot move. For example, you can build two identical grippers made out of Linkbots, then BumpConnect them in a certain way so any motions you make one gripper do, the other will do remotely.

Linkbot's PoseTeaching technology enables the user to program motions into any number of Linkbots to create a motion by manipulating and posing the Linkbot with their hands. PoseTeaching is a new way of programming robots where you record individual poses with the Record button, then play the poses back again by pushing the Play button on the outside of the module. There is also an Erase button, and the routine will loop automatically. You can do very basic repetitive motions, or create complex control paths.

Linkbot's BumpConnect technology enables the user to connect multiple modules by simply pushing the Pair button and bumping the components together. BumpConnect uses the accelerometer and Zigbee-compatible chip to allow any Linkbot to wirelessly connect to any other Linkbot. Once you pair Linkbots, the Zigbee-compatible chip has a line-of-



Several Linkbots charging off four port USB splitters. Some modules are assembled; some do not have their housings.

The Linkbot at the Sacramento Hacker Lab. (This Linkbot appears to be sitting on an ancient-looking vice.)

sight range of 100 meters. "We've driven robots down the block and around the corner," says Graham Ryland, president of Barobo.

More of the Linkbot's Functionality

Linkbot uses absolute encoders which are continuously rotating, and brushed gearmotors to drive the hubs (patent pending).

Linkbot has a multicolor LED with red, blue, and green (RGB) to help tell them apart. Feedback from users stated it was actually hard to tell them apart when they were moving around together. When you BumpConnect, the Linkbots choose a color at random for the group color. There are also Mode colors for TiltDrive (green), CopyCat (turquoise), and PoseTeach (blue).

Linkbot comes with lots of accessories, including SnapConnector mounting surfaces for various SnapConnector parts (wheels, plates, grabbers) that click on to the outside of the Linkbot to form walking robots, and also climbing and rolling robots. You can connect your own accessories using standard screws.

Linkbot accessories are available to download from the



company website, so builders can 3D print them to use with the Linkbot, hopefully design their own, and share them with others. You do not have to have a 3D printer though. Most of the examples in their Kickstarter video and updates are made out of cardboard.

Linkbot also takes advantage of force feedback capabilities. In CopyCat mode, you can feel force feedback when you stop the rotation of the robot you are controlling. It compares the angle of the controller module to the output angle of the controlled module; if they deviate too much, then the motors in the controller robot lock up. It is very early in its development, but it is really engaging and fun to use.

ProtoMold makes Linkbots using plastic injection molded parts. A company called Pride handled the controller board. Pololu supplied the motors.

Conclusion

Barobo's first year of success with Linkbots shows there is a huge interest in these types of robots. Anything that can help spark imagination in children of all age's minds is a good thing. **SV**

Resources

Barobo
www.barobo.com

Rotary Encoders / Shaft Encoders
http://en.wikipedia.org/wiki/Rotary_encoder

Arduino Accelerometers
www.youtube.com/watch?v=HYUYbN2gRuQ

Atmel ATmega 128RFA1
www.atmel.com/devices/atmega128rfa1.aspx

Arduino Controller Boards
www.arduino.cc

Arduino Xbee Shield
<http://arduino.cc/en/Main/ArduinoXbeeShield>

Wireless Arduino Programming with ZigBee
<http://hackaday.com/2008/11/02/wireless-arduino-programming-with-zigbee/>

ASK MR. ROBOTO

by Dennis Clark

Our resident expert on all things robotic is merely an email away.
roboto@servomagazine.com

Tap into the sum of *all human knowledge* and get your questions answered here! From software algorithms to material selection, Mr. Roboto strives to meet you where you are — and what more would you expect from a complex service droid?

You can discuss this topic at
<http://forum.servomagazine.com>.

The summer heat is over. Let the fall and winter robot competitions begin! October sees lots of things happening in the Rockies where I live. Being a total geek, it is time to make cool Halloween costumes about scientists and robots. None of that mamby-pamby sparkly vampire stuff for THIS guy! High tech, rockets, and even steam-punk are the way we roll. Anyway, I'll wrap up my discussion of the RoboBuilder robot and system for the RoboBuilder "Creative" robot. The Action Builder program allows the user to make an autonomous robot that can do some interesting things using its built-in sensors. Finally, I'll show you how to boost your performance with an 11.1V LiPo three-cell battery to replace the 8.4V NiCd pack the kit starts with. Onward!

Question Recap:

Mr. Roboto, I have a RoboBuilder Creative kit that I've had for three years and have just gotten around to experimenting with again. I've been working with the Motion Builder and Action Builder tools to make my own

"moves," but the manual is not very clear about how to build custom motions. I am not having any luck at all with making an Action file. Can you help me Robiwan Kenobi? You may be my only hope!

— Trevor

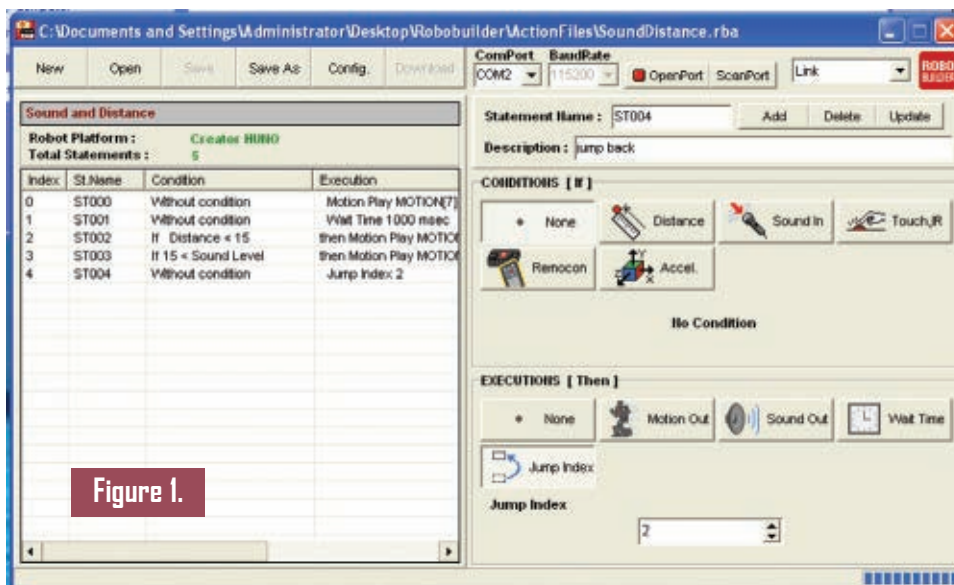
The answer continues ...

Creating Autonomous Behavior with Action Builder

This month, I'm moving on to the RoboBuilder Action Builder program. Action Builder is used to create fully autonomous robotic behavior. It isn't as complex as Motion Builder since you don't have 16 servos, frames, sequences, etc., to account for, but it does use Motion files to carry out its behaviors. The motions are the Motion files that are assigned to the remote control's buttons, so they have to be motions available to the user via the remote. **Figure 1** shows the whole interface.

The left side of the window details the Index, Step Name, Condition, Execution, and finally the description of the steps. The right side of the window handles the specifics of each step. The Statement Name and Description are obvious. Next is the Condition; there are six possible conditions shown in **Table 1**.

The IR distance sensor measures in cm (approximately) and the Sound input is some arbitrary sound level. Level 15 is more or less a hand clap within about 20 cm of the robot. The Action Builder tutorial has a good example (using the accelerometer) that shows how to determine if the robot has fallen down. It is



Conditional Input	Input Description
None	No condition, the chosen Execution always happens.
Distance	Sharp IR range finder (greater, less, equal to, or between); in cm
Sound	Microphone sound level (same ranges as above) in units.
Touch/IR	PF buttons on back of controller, and some kind of sensor.*
Remocon	IR remote control buttons.**
Accel	Three-axis accelerometer (optional).
*The sensor module 1-4 inputs are unknown to me, not in a manual, and not supported (as far as I can tell) on the RoboBuilder Creative robot.	
**The IR remote inputs are not supported on the RoboBuilder Creative robot. This means that Action Builder scripts are NOT interactive.	
Table 1. Conditional inputs.	

Execution	Description
None	Like you would guess, this step does nothing.
Motion Out	Execute a Motion file based upon its assignment on the remote.
Sound Out	On the 5720T, this will play one of 25 prerecorded English phrases.
WaitTime	Wait this number of milliseconds (1/1000 of a second).
Jump Index	Jump to a step index.
Table 2. Step Actions.	

ID	St. Name	Condition	Execution
0	ST000	Without condition	Motion Play MOTION[7]:BTN_C
1	ST001	Without condition	WaitTime 1,000 msec
2	ST002	If Distance < 15	Then, Play Motion MOTION[9]:BTN_LA
3	ST003	If 15 < Sound Level	Then, Play Motion MOTION[11]:BTN_RA
4	ST004	Without condition	Jump Index 2
Table 4. Simple Action Builder action script.			

not useful for dynamic walking. For that, you really need a gyro sensor.

Finally, there is the Execution section. Here you can specify five different outputs for your script step as shown in **Table 2**.

You can access up to 40 Motion files; each button has its regular button press, as well as its "star" button press. The star button press means that you press the asterisk

(star, splat, whatever you call it) at the same time as the remote button to get an action.

You can also turn on/off the LED Module LEDs and turn continuous rotational motors on/off/reverse. These last two don't seem to apply to the Creative kit; I have yet to figure out just what they do.

There are 25 English phrases prerecorded on the Create 5720T

Sound number	Description
1	"Hello, my name is RoboBuilder"
2	"Moving forward"
3	"Moving backward"
4	"Turning"
5	"Moving sideways"
6	"Punch"
7	"Stand up"
8	"Stand up"
9	Cat "meow"
10	Dog "woofing"
11	Dog "arf arf"
12	Dog "whine"
13	Electronic "noise"
14	Dinosaur "roar!"
15	"zero"
16	"one"
17	"two"
18	"three"
19	"four"
20	"five"
21	"six"
22	"seven"
23	"eight"
24	"nine"
25	"ten"
Table 3. RoboBuilder sounds.	

(transparent servos) RBC. You can only get these sounds if your RBC has the sound chip and speaker option.

Table 3 lists what they are. The sounds are pretty easy to understand; the numbers are a little muffled in my opinion. (I personally love the dinosaur "ROAR!" sound!)

Sadly, these sounds can only be used in the Action Builder scripts — I'd love to be able to attach them to Motion files like the buttons on the top of the IR remote control do.

Unfortunately, as with the Motion Builder software, RoboBuilder does not appear to have a user manual for the Action Builder program. The aforementioned tutorial gives adequate information to use all of the capabilities of Action Builder sufficiently, but I've found that there are quirks that you have to find out

ID	St. Name	Condition	Execution
0	ST000	Without condition	Motion Play MOTION[7]:BTN_C
1	ST001	Without condition	WaitTime 5,000 msec
2	ST002	If 20 < Sound Level	Then, Jump Index 4
3	ST003	Without condition	Jump Index 2
4	Fallen1	... and 2 < Z < 6	Then, Motion Play MOTION[2]:BTN_B
5	ST005	If 24 < Distance	Then, Motion Play MOTION[4]:BTN_U
6	ST006	If Distance < 25	Then, Motion Play MOTION[5]:BTN_RR
7	Fallen2	... and -6 < Z < -2	Then, Motion Play MOTION[2]:BTN_B
8	ST008	Without condition	Jump Index 4
9	ST009	Without condition	Jump Index 9

NOTE: For the Fallen1 and Fallen2 St. Names, the actual conditional is:
 If $-1 < X < 1$ and $-1 < Y < 1$ and $2 < Z < 6$
 If $-1 < X < 1$ and $-1 < Y < 1$ and $-6 < Z < -2$
 I just didn't have space to stuff all that into the table and make it understandable. This conditional is looking strictly at the robot lying on its back or on its face.

Table 5. Walkabout Action Builder action script.

for yourself. All of these quirks appear to be caused by the timing of Executions.

For instance, you need to experiment to find the correct time delays to use when you are stringing together "Sound Out" sounds. Otherwise, some of the sounds will overrun others and not be heard correctly.

An Action Builder script is like an old-fashioned Basic program. It is comprised of "IF-THEN" statements and "GOTO" jumps. As with programming Sound Out sounds, these IF-THEN statements have some timing restrictions that you have to experiment with to get to work.

For instance, I can get a "Sound Level" Condition to work and an "IR

Range" Condition to work, but I can't get both to work together in some script loops. I have yet to figure out when the RBC "hears" something as opposed to when it reads a range from the IR range finder, accelerometer, and executes a Motion file. When I do, I'll have a pretty cool script!

Each time you start a new session (turn your robot on), you start over with respect to the order of Action Builder scripts. This is the same behavior as Motion Builder downloads. When you start an Action Builder script, it runs until you power-cycle the unit or until its script stops. The only way to regain control of your robot again is to power-cycle it.

I heard a rumor on one of the RoboSavvy forums that said there was an IR remote control key sequence you could do to jump out of the Action Builder script and run the regular robot mode, but I was unable to get this to work. I forgot what forum page that hint was on and my *Google-foo* has not been up to the task of finding it again.

You can use the RoboBuilder Tool to download Motion files in proper order all at once; when downloading Action Builder scripts, you have to do them as well. The first action script is "# - 1" on the IR remote control; the second is "# - 2" and so on.

So, Action Builder isn't a perfect tool, but it mostly works. Now, let's create a simple action script that won't leap off of our workbench when we test it.

This Action Builder script will punch one direction when something is closer than 15 cm to the robot's head, then it will punch the other direction when it hears something that is louder than sound level 15. It then jumps back to the beginning of the script and keeps it up.

Table 4 shows the script settings.

When you have entered all of these, press the **Save** button

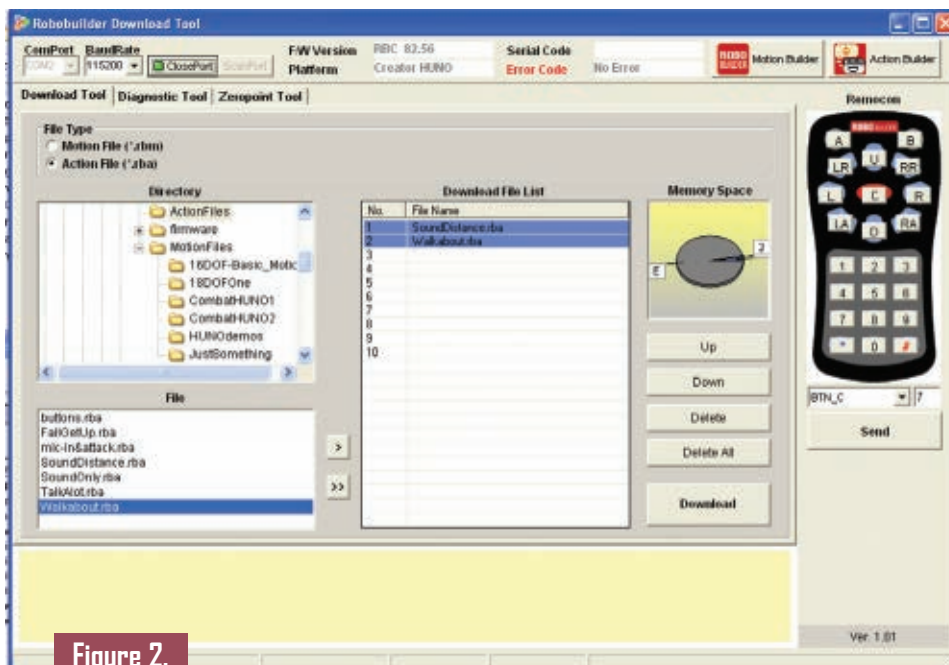


Figure 2.

to save the script to disk, and then press the **Download** button to store it to the robot. To run the script, press the “#” – “1” together on the IR remote and see how it works.

With this Action Builder script, the robot will punch right when it hears a loud noise and punch right when anything comes within 15 cm (more or less) from in front of its head. The script starts out by running the Initial startup pose and announcing sound 1 – “Hello, I am Robo Builder.” It then waits a second, then starts its loop.

Here’s an exercise for you. Can you come up with an Action Builder script that will allow your HUNO robot to wander around and turn away from obstacles in front of it? Sure you can!

If you have an accelerometer installed, maybe you can get your robot to stand up if it falls over during its wanderings, as well.

Okay, you’ve bent my arm. Here is a script that will walk forward, turn if something is within 25 cm, and get up if the robot falls over.

I just didn’t have space to stuff all that into **Table 5** and make it understandable. This Condition is looking strictly at the robot lying on its back or on its face.

Steps 2 and 3 simply loop with the robot standing there, until it hears a loud sound; then it starts walking. If it sees something in front of it, the robot keeps turning right until the path is clear. Then, it starts walking forward again.

Step 9 was there initially when I was trying to get the robot to hear another noise or see something really close to itself to trigger it to stop the script. I was never able to make either of those circumstances work.

If anyone manages to find something other than a button press of FP1 or FP2 to work to stop the script, please send me your solution and I’ll publish it and make you famous for a day!



Figure 3.

You now have two Action Builder scripts that you can download to your robot. The easiest way to do this is to

use the RoboBuilder tool as shown in **Figure 2** and download the two scripts at once into slots #1 and #2.



Figure 4.

Figure 5.



Upgrade for the RoboBuilder to a 11.1V Three-Cell LiPo Battery

I first approached this by

installing a 1,050 mAh two-cell LiPo in my HUNO robot. This worked fine and got me more run time than the included seven-cell NiMh 800 mAh pack. The battery pack needs to be 12 mm thick to fit. See **Figure 3** for my two-cell install.

There is a firmware version (RBC 82.56) that allows a 11.1V LiPo to work properly and turns off the battery charger circuit (so you don't burn your robot up!). You can find the RoboSavvy Wiki page at http://robosavvy.com/site/index.php?option=com_openwiki&Itemid=&id=robobuilder.

It shows you where to get this firmware. The thinnest 1,000 mAh three-cell pack I could find was the Turnigy nano-tech 1.0 1,000 mAh battery pack at **HobbyKing.com**; it was 17 mm thick.

This doesn't quite fit, but it will work if you don't mind some interesting hacks and soldering iron work. As you can see in **Figure 4**, the battery fits inside the case but the back won't install anymore.

If we remove the large white battery connector you can see in **Figure 3** and replace it with a different direct-connect RC radio battery connector, we can pull 3 mm out of the stack.

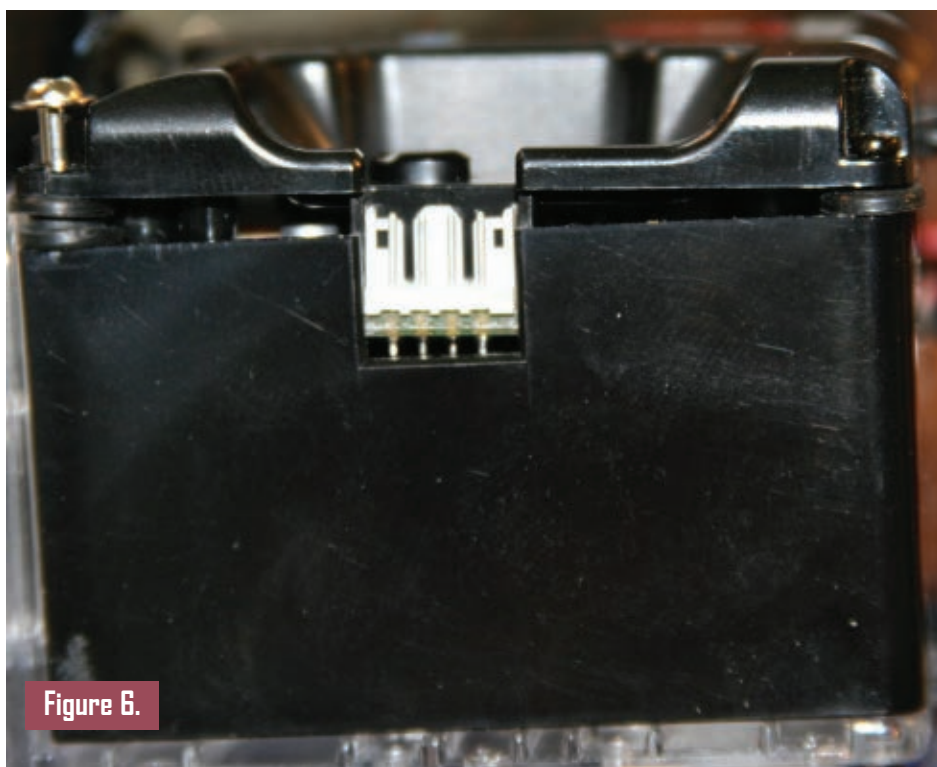
It's still not enough, but enough to *mostly* get the battery in and the back to bolt back on (see **Figure 5**). A little dab of hot glue holds the wire in place and keeps it from stressing the wire joint to the printed circuit board.

This isn't perfect and the case won't quite settle all the way down, but with a trip to the good 'ol junk bin I found a couple of servo screws and servo shock mounts that I trimmed to keep the back from cracking when the robot fell down.

As you can see in **Figure 6**, I have a bit under a 2 mm gap (caused entirely by the trimmed shock mount rubber) at the top of the RBC and a 3 mm gap at the bottom of the RBC cover. The rubber shock mounts prevent me from cracking the back if (when) the HUNO falls over.

Because I like to protect the expensive parts of my robots a little bit, I added another measure of protection by finding a couple of screws that were long enough (but not too long) to hold two of the "J7"

Figure 6.



corner mounts that came in my 5720T kit to the main body frame back plate (**Figure 7**). On a major back fall smack-down, these will take the brunt of the force of the fall, sparing my RBC.

It is important now to install the 11.1V firmware to protect the battery from an accidental activation of the internal battery charger. Use the *RBCUpgradeTool.exe* program to do this. This tool is super simple and straightforward.

Use the tool to navigate to where you saved the RBC82.56 firmware, set the proper COM port, and configure things as shown in **Figure 8**. Press the "Click here and Push Reset Button" button, then push the "Reset" button on the back of the RBC.

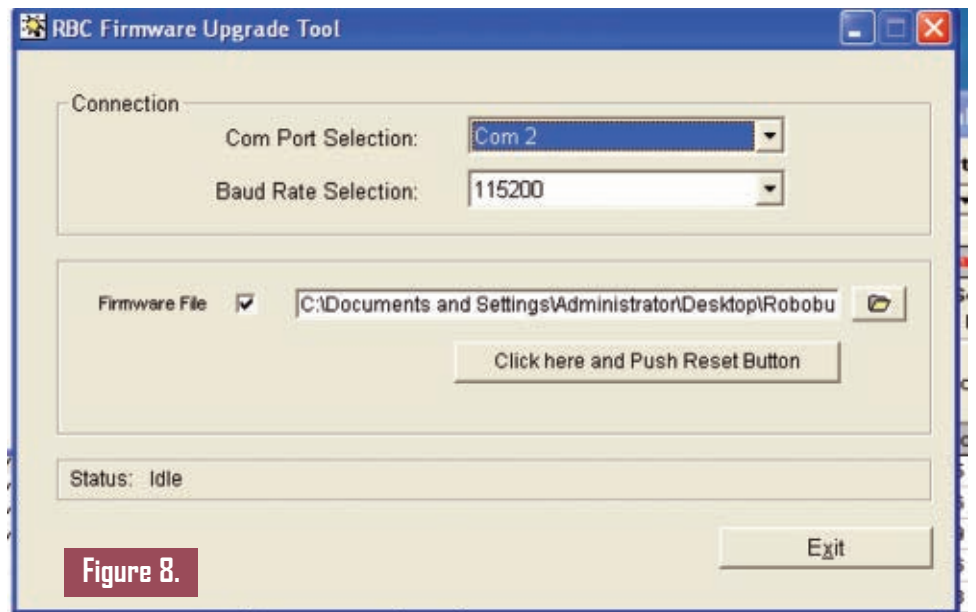
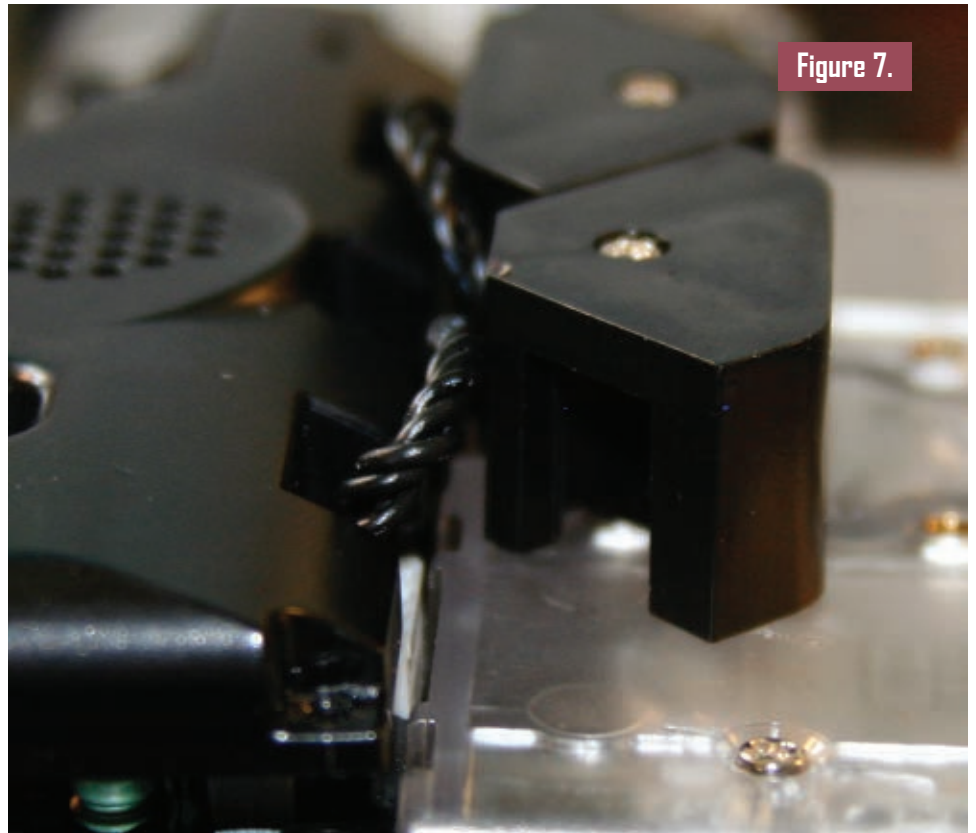
The reset button is actually hidden; it's under the tiny hole between the LEDs next to the **PF1** and **PF2** special function buttons on the right side of the back of the RBC. (Make sure the RBC is turned on first!)

The "Status" window on the Firmware Upgrade tool will start counting down the packets being loaded into the RBC. This should take about 20 seconds to complete.

Voila! You now have an 11.1V LiPo based HUNO! You will immediately notice that its movements are a lot snappier.

All the posts on the RoboSavvy forum site say to upgrade your servos to all-metal gears, but my experience shows that you don't need to do that if you have the 5720T kit with the transparent servos that have the metal output shafts (but plastic internal gears).

Try it on the 5710K kit and see if everything works okay. If you start stripping gears, then you can back off to a two-cell 7.4V LiPo, or drop another US\$8 a piece on all-metal gear sets. Choose the expense path you are comfortable with.



Well, that's it for another month! Please keep those cards and letters (well, emails actually) coming and I'll do my best to answer them! You can contact me at roboto@servo magazine.com. **SV**

Know of any robot competitions I've missed? Is your local school or robot group planning a contest? Send an email to steve@ncc.com and tell me about it. Be sure to include the date and location of your contest. If you have a website with contest info, send along the URL as well, so we can tell everyone else about it.

For last-minute updates and changes, you can always find the most recent version of the Robot Competition FAQ at Robots.net: <http://robots.net/rcfaq.html>.
— R. Steven Rainwater

or outdoor flight that involves take-off, navigation of an obstacle zone, and landing.
www.imav2013.org

20-23 RoboCup Junior Australia
UQ Centre, University of Queensland, St Lucia Brisbane, QLD, Australia
In addition to standard RoboCup soccer events, there will also be robot dance and robot rescue events.
www.robocupjunior.org.au

need of assistance. Once found, the UAV must drop a mock emergency package nearby and report the human's position back to base.
www.uavoutbackchallenge.com.au

27 Robots Intellect Championship
Kaunas, Lithuania
Autonomous robots must find and retrieve a 1 kg "bag of gold." (Note: there's a chance the date of this event may change by this time this goes to press, so please check the website for the latest information.)
www.robotsintellect.lt

SEPTEMBER

2-6 World Robotic Sailing Championship
Brest, France
Robot sailboats must navigate an ocean course around buoys.
www.roboticsailing.org

11-14 Sumo.uy
Udelar, Montevideo, Uruguay
Lots of events for autonomous robots including Sumo, Liceal, LARC IEEE Open/SEK, line following, and vision.
www.fing.edu.uy/sumo.uy

14 National Junior Robotics Competition
Science Centre, Singapore
Primary, secondary, and university teams design autonomous robots that must perform a variety of tasks that vary each year. A panel of judges rate the performance.
www.njrc.com.sg

17-20 International Micro Air Vehicle Competition
Toulouse, France
Open to Micro Air Vehicle teams from any country. MAVs must demonstrate a high level of autonomy in either indoor

21 Robothon
The Armory, Seattle Center Seattle, WA
This year's events include Robo-Magellan, line following, line maze, and mini Sumo.
www.robathon.org/robathon

21 Robotour
Lódz, Poland
Can your autonomous robot navigate through a public park carrying a five liter barrel of beer?
www.robotika.cz

23-27 euRathlon
Berchtesgaden, Germany
Autonomous, outdoor, off-road robots must respond to simulated emergency response scenarios inspired by the Fukushima accident. Robots must survey the accident scene, collect environmental data, and identify critical hazards.
www.eurathlon.eu

24-25 UAV Outback Challenge
Calvert, Queensland, Australia
UAVs must search a rural Australian outback area for a dummy representing a stranded or lost human in

OCTOBER

4-5 CalGames
Woodside High School San Jose, CA
A FIRST-based robot event for high school teams.
www.wrrf.org

18-20 Critter Crunch
Hyatt Regency Tech Center Denver, CO
Autonomous and remote-control robot combat at the MileHiCon science fiction convention.
www.milehicon.org

18-20 Latin American Robotics Competition
Fortaleza, Brazil
Events include the Brazilian Robotics Competition, RoboCup Latin American Open, the Brazilian National Olympiad, and the National Robotics Fair.
www.cbrobotica.org

NOVEMBER

- 8-9 Texas BEST Competition**
*Curtis Culwell Center
 Garland, TX*
 Remote-control robots built by student teams face off in an annual contest.
www.bestinc.org
- 9 STHLM Robotic Championship**
Stockholm, Sweden
 Autonomous robots compete in events that include Sumo, folk-race, line following, and freestyle.
www.robotchampion.se
- 10 International Micro Robot Maze Contest**
*Nagoya University,
 Japan*
 1 cm cube robots compete in Micro Robot Racer and the Climbing Competition; one inch cube robots compete in Maze Solver; and there's even a two-legged robot event for tiny two inch biped robots.
<http://imd.eng.kagawa-u.ac.jp/maze>

Recycling & Remarketing High Technology
WEIRDSTUFF®
 WAREHOUSE
 Software, Computers, Electronics, Equipment, Doo-hickies
**384 W. Caribbean Dr.
 Sunnyvale, CA 94089**
 Mon-Sat: 9:30-6:00 Sun: 11:00-5:00
 (408)743-5650 Store x324

 **WE BUY AND SELL EXCESS & OBSOLETE INVENTORIES!**

FREE COMPUTER RECYCLING
 We recycle computers, monitors, and electronic equipment. M-Sat 9:30-4:00 

 **GREAT DEALS!**
 Hi-tech items, electronics test equipment, and more!

GIANT AS-IS SECTION
 10,000 sq. ft. of computers, electronics, software, doo-hickies, cables, and more! 

also check out our...
 **Store**
stores.ebay.com/WeirdStuff-Inc
WWW.WEIRDSTUFF.COM

ALL ELECTRONICS CORPORATION

Thousands of Electronic Parts Available Today!

LEDs • CONNECTORS • RELAYS
 SOLENOIDS • FANS • ENCLOSURES
 MOTORS • WHEELS • MAGNETS
 PC BOARDS • POWER SUPPLIES
 SWITCHES • LIGHTS • BATTERIES
 and many more items...

We have what you need for your next project. 

www.allelectronics.com
 Discount Prices • Fast Shipping

SERVO

SERVO BOOK SPECIALS

PRACTICAL ELECTRONICS FOR INVENTORS

Free STD Shipping!

Programming the Raspberry Pi
 Getting Started with Python

Raspberry Pi User Guide

Raspberry two book combo

For more specials and subscriber discounts please visit:
<http://store.servomagazine.com>
 Offer Ends 9/31/13

Small Mechanical Components for

ROBOTICS

800-819-8900

Setting Ideas in " to Motion
SDPSI

Visit sdp-si.com and Buy Online Today.

NEW PRODUCTS

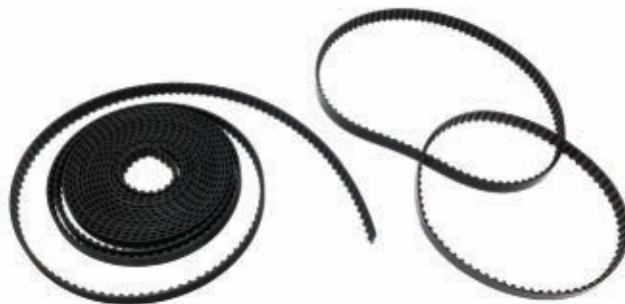
Stainless Steel Screw Plates

ServoCity now offers a full line of stainless steel screw plates. These plates have 6-32 tapped holes that align with their Actobotics™ pattern to allow for quick and solid attachment of multiple parts. Using screw plates as opposed to hex nuts will allow the load to be spread throughout a larger area for greater strength. The design allows screws to be tightened without the need to back the opposing side with a wrench. The stainless steel construction offers outstanding durability for those who like to build and take things apart time after time. Plates start at \$1.49 each.



Timing Pinion Pulleys and Timing Belt

The product line of pulleys and belts at ServoCity has recently been expanded. XL series timing pulleys are now offered in both 6 mm and 1/4" bore. The 6 mm bore pulleys slide right onto many of the motors that ServoCity offers, while the 1/4" bore pulleys are excellent for building idlers and drives with their 1/4" shafting. These pinion pulleys fasten tightly to a shaft by tightening the 10-32 set-screw. The 6061-T6 aluminum construction ensures excellent strength and durability.



ServoCity also offers hub pulleys which have a 1" bore and a 1.5" hub pattern, commonly used in conjunction with a small pulley on a gearmotor for a ratio reduction. To complement the

pulleys, ServoCity also offers 3/8" wide XL series timing belts that are directly compatible with their entire line of XL series hub and pinion pulleys. They offer belting by the foot for large applications, but also carry a variety of sizes in continual belt loops.

For further information, please contact:

ServoCity

Website: www.servocity.com

Eight-bit Microcontroller Family With Intelligent Analog Integration Expanded

Microchip Technology, Inc., announces an expansion of its eight-bit PIC16F178X enhanced mid-range core microcontroller (MCU) family with increased Flash memory densities; intelligent analog and digital peripherals, such as on-chip 12-bit analog-to-digital converters (ADCs); 16-bit

PWMs, eight-bit and five-bit digital-to-analog converters (DACs); operational amplifiers; and high-speed comparators with 50 ns response time, along with EUSART (including LIN), I²C, and SPI interface peripherals.

The PIC16F178X are the first MCUs to implement the new programmable switch mode controller (PSMC), which is an advanced 16-bit pulse-width modulator (PWM) with 64 MHz operation and high-performance capabilities.

This combination of features enables higher efficiency and performance, along with cost and space reductions.

The new MCUs also feature eXtreme low power (XLP) technology for active and sleep currents of just 32 $\mu\text{A}/\text{MHz}$ and 50 nA, respectively, helping to extend battery life and reduce standby current consumption.

Low power consumption in combination with advanced analog and digital integration make the PIC16F178X MCUs ideal for LED and other lighting applications, battery management, digital power supplies, motor control, and general-purpose applications.

Available in 28- and 40-pin packages, the MCU's intelligent analog integration paired with core independent peripherals — inclusive of the PSMC, DACs, op-amps, high-speed comparators and 12-bit ADC — enable self-sustaining smart control loops with minimal CPU intervention. This allows for optimal application control while freeing the CPU to provide incremental application value such as system health monitoring, communications, or human interface control. Additionally, the MCUs feature a 32 MHz internal oscillator, two 16K words (3.5 - 28K bytes) of Flash, 256 - 2K bytes of RAM, and 256 bytes of data EEPROM.

Initial evaluation and development of the PIC16F178X family can quickly begin with the F1 PSMC 28-pin evaluation board platform (part #164130-10, \$19.99). Additionally, the PIC16F178X family is supported by Microchip's standard suite of development tools, including the PICKIT™ 3 (part #PG164130, \$44.95), MPLAB® REAL



ICE™ (part #DV244005, \$499.98), MPLAB ICD 3 (part #DV164035, \$189.99) debuggers/programmers, and the MPLAB XC8 compiler.

The PIC16(L)F1782/3/4/6/7/8/9 MCUs are available now for sampling and volume production in 28-pin SOIC, SPDIP, 6 x 6 mm QFN, and 4 x 4 mm UQFN; as well as 40-pin PDIP, TQFP, 8 x 8 mm QFN, and 5 x 5 mm UQFN packages. Pricing starts at \$1.18 each, in 10,000 unit quantities.

For further information, please contact:

**Microchip
Technology, Inc.**

Website: www.microchip.com

Three-Axis Accelerometer

Saelig Company, Inc. has introduced the PP877 three-axis accelerometer which includes a signal conditioning interface suitable for any three-input oscilloscope. It is especially suited to Pico Technology's four-channel PC oscilloscope adapters. Designed for vibration and acceleration experiments, this three-axis accelerometer and



interface simply plugs into any PicoScope oscilloscope to provide a $\pm 5\text{g}$ measurement range for movement and vibration investigations from DC to 350 Hz frequency range.

The PP877 accelerometer sensing head has mounting options of either a built-in powerful magnet or a mounting hole for screw-attachment. Powered by an internal 3V lithium battery, the PP877's signal conditioner output is from 0 to 2 VDC, with 0g at 0.85V to 1.15V output (all axes), and output scaling of 99 to 122 mV/g. The sensor head has been designed for shock survivability to 10,000 g and has an operating temperature range of -40°C to 85°C .

The free supplied PicoScope 6 software makes it easy to quickly see the output of each of the three axes' outputs when used with a suitable PC oscilloscope such as the PS4424.

The three-axis accelerometer consists of a sensor head, a signal conditioner, three BNC cables, and a Quick Start guide. It is available now from around \$400.

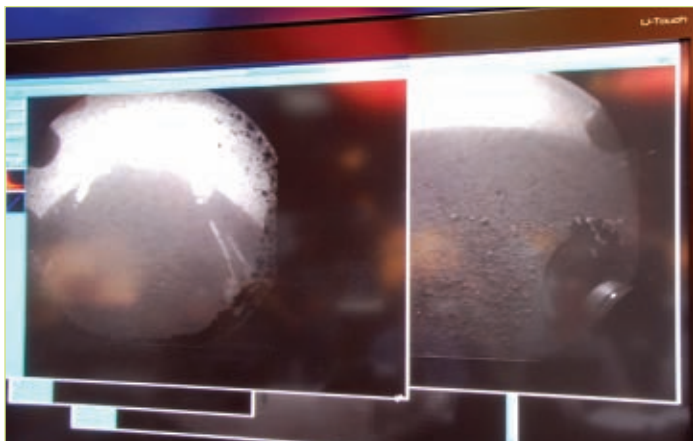
For further information, please contact:

Saelig

Website: www.saelig.com

Continued on page 65

bots IN BRIEF



CURIOSITY TURNS ONE

August 6, 2013 marked the first anniversary (or birthday) of Curiosity — NASA's intrepid Volkswagen-sized Mars rover. Curiosity is one of the most awesome robots ever constructed. The photo is of a TV monitor in the JPL press room, showing the first two images that we got back from the surface of Mars. It was epic.

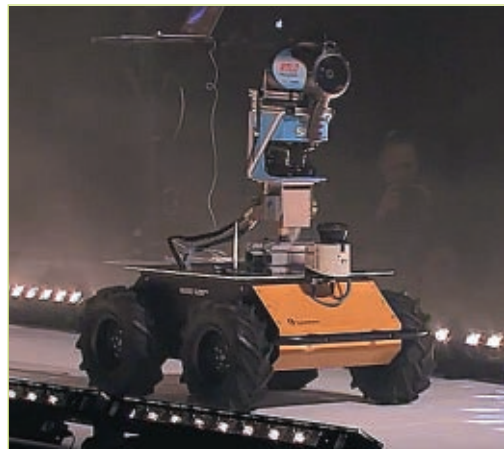
There's an awesome video at <http://spectrum.ieee.org/automaton/robotics/aerial-robots/curiosity-turns-one-on-mars> of Curiosity playing herself happy birthday using a special sequence of vibrations from the Sample Analysis at Mars (SAM) instrument. It is epic, as well.

YOU'VE GOT GAS

Jobs don't get much more dirty than being the person who has to hike around landfills looking for sources of odor. It's an important job, though, because bad smells mean methane. Figuring out where landfills are leaking is a critical and tedious (and decidedly unpleasant) thing, so you know what that means — bring on the robots!

Gasbot is a project from the AASS Research Centre at Orebro University in Sweden. It's a Clearpath Robotics Husky A200 mobile robot (awarded for free through Clearpath's Partner Program) equipped with a pair of laser scanners, a GPS, and a remote gas sensor. Specifically, we're talking about a tunable laser absorption spectrometer which provides integral concentration measurements of gasses over the path of the laser beam.

All you have to do is let Gasbot roam around a site where you think you might have gas leaks and it will build up a map of concentrations and locations for you.



ATTACK OF THE GIANT CRAB

Next time you're basking on the beach, watch out for giant crab robots.

The Crabster CR200 — a huge six-legged underwater robot — took the plunge last month for the first time. Developed at the Korean Institute of Ocean Science and Technology (KIOST), the Crabster is an alternative to propeller-driven remotely-operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) which are often ill-equipped to deal with strong tidal currents in shallow seas.

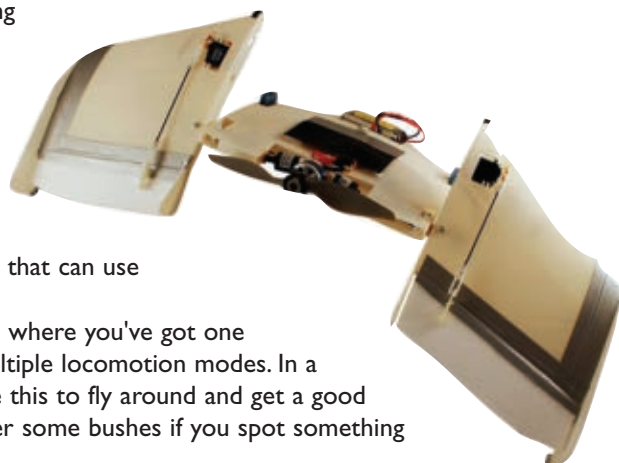
WINGING IT

Here's a new robotics term for you: multi-modal locomotion. It means locomoting in multi-modes, which is basically getting around in more than one different way. Most animals are multi-modal. They can walk and swim, or walk and fly. This isn't a coincidence because there are clear advantages to being able to move multi-modally, with capability and efficiency coming out near the top of that list.

The disadvantage is that, generally, you need a substantial amount of extra hardware for each mode of locomotion. However, EPFL has managed to create a UAV that can use its wings to walk.

This robot takes advantage of "adaptive morphology," where you've got one structure (the wings, in this case) that can be used for multiple locomotion modes. In a search and rescue situation, you might use a capability like this to fly around and get a good overview of an area, and then land and crawl around under some bushes if you spot something interesting.

Also, small UAVs tend to land badly, and being able to move around (even just a little bit) vastly improves the potential for returning to the air successfully.



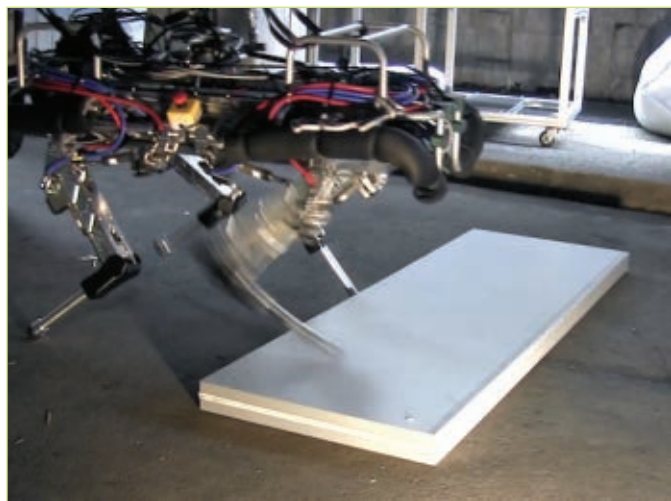
HIGH-STEPPING HyQ

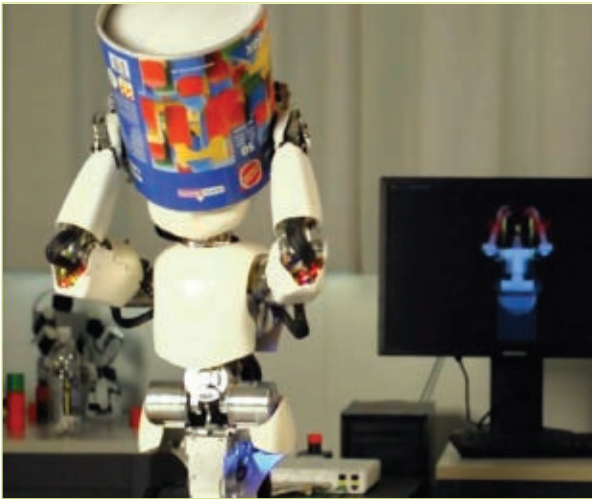
HyQ is a quadruped robot designed for rough terrain missions. Created by a team at the Istituto Italiano di Tecnologia (IIT), HyQ uses hydraulic actuators which allow it to move quickly and nimbly with an eerie animal-like quality. Now, HyQ has learned another important skill in life: how not to fall on its face when it stumbles on an obstacle.

Falling is a major problem for legged robots. Unlike animals and (most) humans, robots don't handle falls very well. Their stiff metal bodies can't absorb shocks, and a crash often means broken parts and costly repairs. So, robots designed to operate in real world conditions need to learn how to avoid falls. Cameras and sensors like LIDAR help detect and avoid obstacles, but in some situations a robot can't rely on vision. For example, in thick vegetation or if smoke is present.

To overcome this obstacle (quite literally), HyQ is learning to reflexively react when its legs hit an object on the ground. This reaction has to be very fast — especially when the robot is trotting (HyQ can reach two meters per second) — or else it will lose its balance and collapse.

The IIT researchers have developed and implemented a "reflex algorithm" that allows HyQ to step over high obstacles without prior knowledge of the terrain.





HEADED FOR TROUBLE

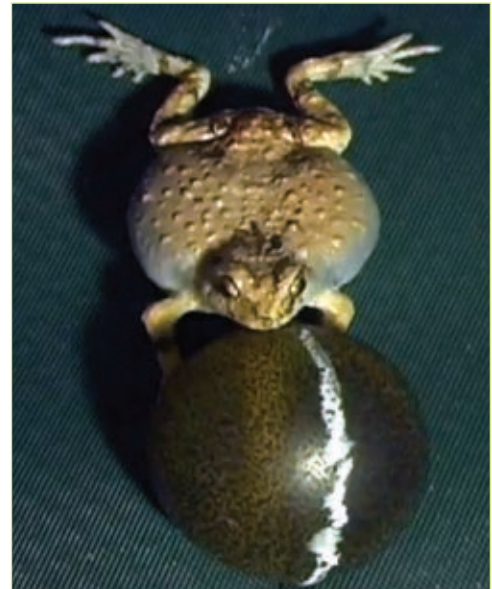
Robots have a tendency to move a lot like, well, robots. The smooth and natural motions that we humans are so proud of comes from a combination of many different motions all at once. If you pick something up, you're generally not just using your arm like a robot does, but rather, subtly moving your arms, wrists, hands, torso, and even your head.

With a new movement algorithm, iCub is learning to move in a much more human-like manner, even with complex motions.

Yes, iCub has learned how to put things on its head.

LEAPING LOVERS

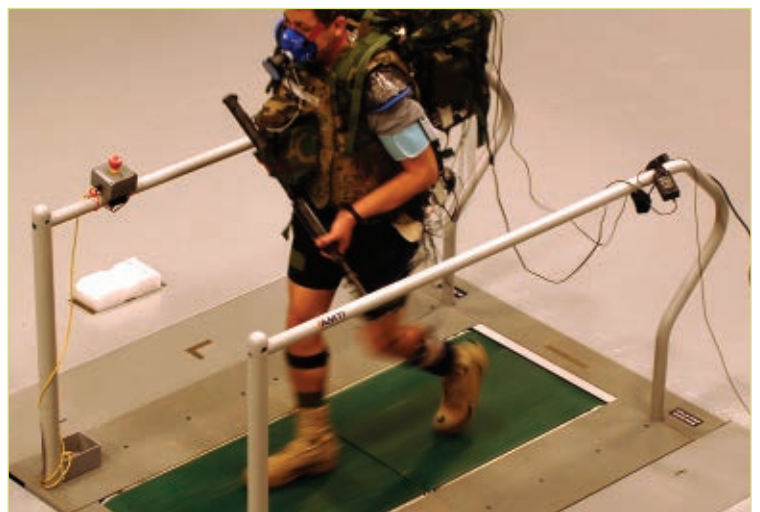
No species (especially humans) is particularly clever when it comes to properly interpreting mating calls. Let's take the túngara frog as an example. Someone made a robotic one, so we can talk about it. The female túngara frog (they can be found hopping around most of Central America) relies on vocal and visual displays from male frogs to find a suitable mate. However, researchers have made a "rather bizarre" discovery that a robotic version of the frog can attract females by hacking into their evolutionary aptitude for filtering out white noise.



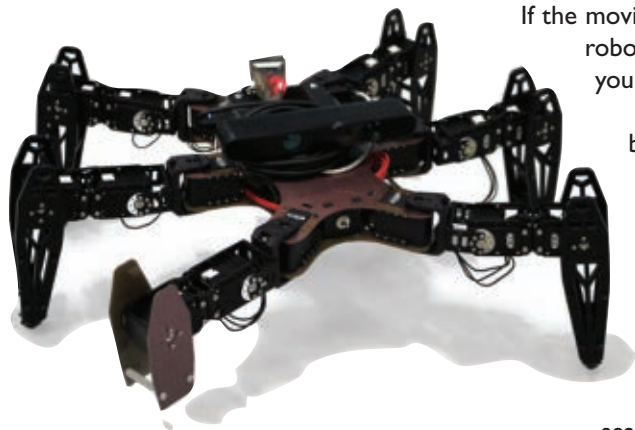
WARRIOR SUIT

While it may not be quite up to Tony Stark's standards, DARPA's Warrior Web suit has the advantage of being real. Warrior Web is a flexible exoskeleton suit that uses only 100 watts of power. The goal is to reduce the injuries and fatigue that result from a soldier carrying a typical 100 pound load for extended periods of time. DARPA hopes the exoskeleton will boost the soldier's endurance and carrying capacity.

According to DARPA, the Warrior Web program seeks to develop the technologies required to prevent and reduce musculoskeletal injuries caused by dynamic events typically found in the warfighter's environment. The ultimate program goal is a lightweight conformal under-suit that is transparent to the user (like a diver's wetsuit). The suit seeks to employ a system (or web) of closed-loop controlled actuation, transmission, and functional structures that protect injury-prone areas, focusing on the soft tissues that connect and interface with the skeletal system.



GREAT GAIT!



If the movies have taught us anything, it's that chopping a futuristic death robot's leg off does not significantly diminish its capacity to hunt you down.

Now, there's a real robot who can work when "injured." This bot has a five-legged gait that moves it along at 18 cm/s, as compared to the undamaged 26 cm/s gait. Not bad, considering that an unmodified five-legged gait had it limping along at just 8 cm/s.

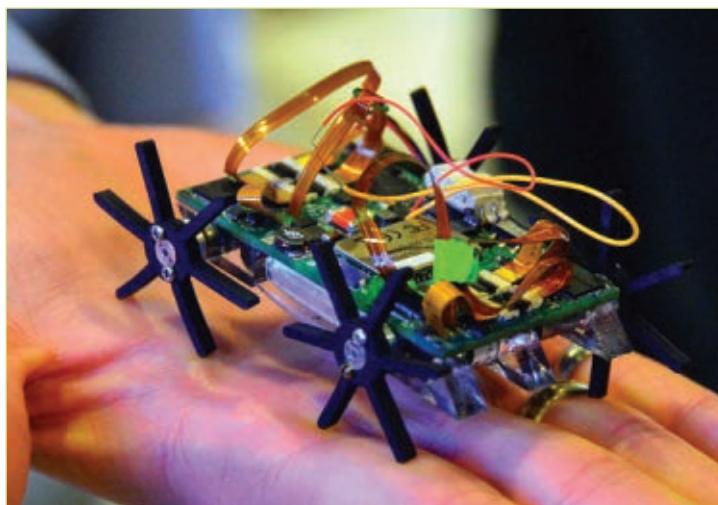
The cool thing about this recovery model is that it doesn't require any specific information about what parts are malfunctioning or missing. Instead, it's just got a known model of how it's supposed to work, and if the actual performance that it measures is less efficient, it starts searching for new behaviors.

To get all sciencey about it: "The robot will thus be able to sustain a functioning behavior when damage occurs by learning to avoid behaviors that it is unable to achieve in the real world." Umm ... are we sure this is a good thing?

WHEGS GONE WILD

This little legged robot from Johns Hopkins is quick. It can travel at over 30 body lengths every second, which works out to over two meters per second (or four and a half miles an hour). If you were travelling at 30 body lengths every second, you'd be going 122 miles an hour. Yeah. Think about that.

This robot — which still doesn't have a name — is very compact (just 6.5 x 5.5 x 1 centimeter), and according to its creators is quite possibly "the fastest legged robot of its size." Whether or not this really is a legged robot (or a quadruped) is perhaps debatable. These are wheel-legs, more commonly known as whegs.



They're wheels in that there's rotary motion going on, but they're also legs in that there are discrete points of contact with the ground. To some extent, whegs offer the best of both worlds. They can be directly driven with conventional motors, and allow for high speed and efficiency while simultaneously providing traction over rough terrain and obstacles. Plus, you can easily swap them out and by making them out of springy materials, you can give your robot some compliance.

What makes this robot wicked fast is the fact that it's got four independent drive motors — each one of which has a power-to-weight ratio that's absolutely bananas. Only six millimeters in size each, the motors output 1.5 watts of power at 40,000 RPM, driving the individual whegs through 16:1 planetary gearheads. They're not cheap (hundreds of dollars each), but they make for one crazy little robot. Of course, independently driven whegs make the robot smaller, lighter, simpler to steer, and generally more efficient overall.

Unfortunately, the current generation of this robot isn't capable of taking advantage of all of the power that the motors offer. Even at top speed, it's only using about 0.60 watt — less than half of what the motors can output — since increasing wheel speed causes the robot to bounce along the ground, decreasing its actual speed. There's a lot of potential for swapping in some new whegs up to 35 mm in length (about twice as long as those currently on the robot) "which might produce even faster running speeds and the ability to navigate very large obstacles or challenging terrain, with a robot that still fits in your hand."

COMBAT ZONE

Featured This Month:

28 BUILD REPORT: *Tanto*

by Craig Danby

30 CARTOON

31 *Then and Now — A Decade Later With Richard Stuplich*

by Kevin M. Berry

33 *Orangutan Drives Fleaweight!*

by Zachary Witeof

34 PRODUCT REVIEW: *Botbitz 30A ESC*

by Zachary Witeof

Go to www.servomagazine.com/index.php?magazine/article/september2013_Combat_Zone for any additional files and/or downloads associated with this article. You can also discuss this topic at <http://forum.servomagazine.com>.

BUILD REPORT:

Tanto

● by Craig Danby

For the last 16 years, I have been building and competing in robot combat. You name it, I've probably built it — from walkers to brick bots to full power flippers to hydraulic crushers in almost all weight divisions. I've even gone as far as building my own heavyweight scale arena, which is where my build report begins.

In 2009, we set up an event and built a 30' x 30' steel arena with the long-term plans of getting spinning weapons back in the UK (which were banned back in 2006). Sadly, this plan was scuppered by a very small thing. I was diagnosed with Leukaemia. The arena went, my robots went, and eventually all the parts for a robot went. At my worst in 2010, I had given up completely on my robot combat dreams.

The therapy took its toll. I had good days and bad days. On one of the bad days, I flicked through some old robot photos, finding it a great distraction. For

the next few days, I sketched robots of various shapes, sizes, and styles. Late one night, I looked through my designs and saw something I couldn't stop thinking about. I designed versions with various add-ons and internal setups, but the shape was the same. Finally, I settled on one internal setup, one shape, one style, and one idea.

The design was a slim-bodied robot four inches thin. Overall, it's 25 inches long and 20 inches wide, with two 10 inch wheels. It's tiny for a heavyweight, but why so small?

To be able to repel the spinners in the US, the front needed to be thick steel. The forks are solid 3-1/2 inch high carbon steel and make up over 50% of the length of the robot. The back end is a half inch thick, and the rear, sides, top, and bottom are 3/8 inch thick steel. Again, why so small?

With a smaller surface area, I can increase the amount of

protection while creating a smaller target for the opposition to hit. It also has high ground clearance.

Arenas are rarely as flat as they could be, so it's best to overcompensate. Also, the thin body means I can decrease the gradient of the wedge to make it much easier to slide under competitors and shove them around. Two three inch motors running on 28V driving 10 inch wheels on a 6:1 ratio makes that sliding pretty high impact at 25 mph.

The big question: Why the forked front? Do I like forklifts or pallet trucks? No, not especially! The forks give a huge advantage when trying to get under something.

Why? Have you tried sliding a piece of paper under another piece of paper? It doesn't work very well since the paper has a large surface area it's trying to push under. A stiff pin or a knife, on the other hand, gets under a sheet of paper very well. Also, the split front works nicely against spinners. When spinning weapons hit weapon to weapon, usually one flings the other away.

Because the robot is so solid and 50% of the weight of the robot is at that end, it acts like a counter strike. By using the force of their weapon to slam me about, I transfer that back to them simply by Tanto's shape.

By the time I felt well enough to



work and earn money to build Tanto, I was living in Madrid, Spain. I bought the steel; a few weeks later, the drive and internals; and just before Christmas 2012, I found a workshop to use.

Have you tried cutting three inch high carbon steel? It eats grinding discs and spits out tiny white hot tears of laughter as you attempt to cut it! Nine hours later, I had finally cut one side of one fork out ... this was not working! Avast! In yonder corner! A plasma cutter!

I approached the nice man using it, and a lot of pleasantries and 50 Euros later, he cut my steel for me.

The next morning, I arrived primed and ready ... let's weld this sucker! The nice plasma cutting man wheeled out a lush TiG welder and

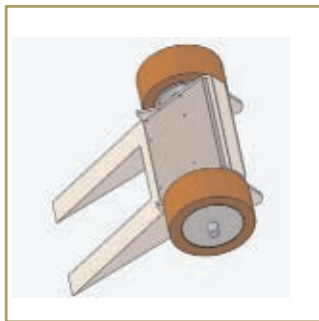
off to work I went. A full day later, and the beast was done. And by beast, I mean the welder. It was out of gas, but by tomorrow my work would be done, so with one final push, the robot was finished. Not bad for three days' work.

The year ticked over to 2013 and with the new year came a new job back in England. Within a week of being back, the internals were mounted, the wheels and shafts were machined and added, and finally she (my bot) looked done.

Even better than looking done, she looked like my design from my sketch book and the later SolidWorks drawings I did. It was a proud moment. The robot that had helped drag my mind away from the pain and illness I suffered, the design that I toiled over day and night, the robot I had worked so hard to actually build, was done and finally ready to return me to my beloved sport.

While Tanto is to many simply a wedged brick on wheels, it's much more than that. To me, it's a symbol of overcoming suffering; it's a symbol of determination. Its impenetrable armor and outright speed shows that she will deflect the blows that would stop weaker robots.

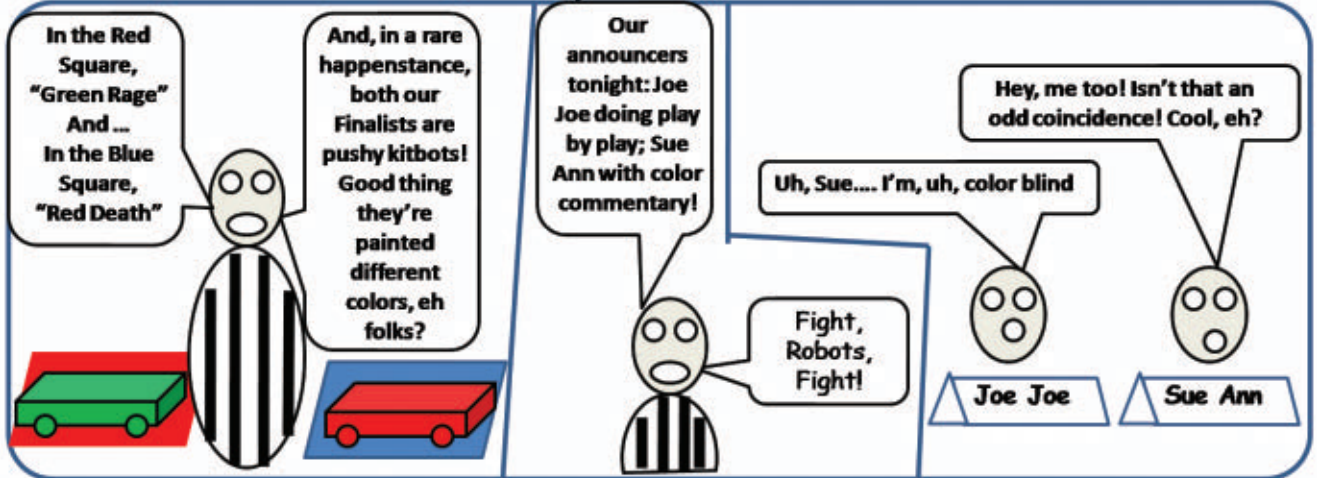
She is my way of fighting what I cannot, and most importantly of all, she is a dream realized. **SV**



Melty Brains

Tales of RoboGames

by Kevin Berry



Unfortunate Announcer Pairings ...

AndyMark
Inspiring Mobility

Specializing in Unique Wheels,
Gearboxes, Aluminum Sprockets
and Drive Bases



8" Plastic Omni Wheel



c-Rio-Ready Full
Chassis Kit



Aluminum Sprockets

6" HD Mecanum Wheel Set

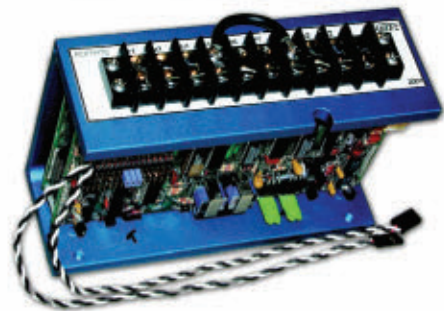


AndyMark, Inc.
sales@andymark.com

Toll Free: 877-868-4770

www.andymark.com

**STEER WINNING ROBOTS
WITHOUT SERVOS!**



Perform proportional speed, direction, and steering with only two Radio/Control channels for vehicles using two separate brush-type electric motors mounted right and left with our **mixing RDRF dual speed control**. Used in many successful competitive robots. Single joystick operation: up goes straight ahead, down is reverse. Pure right or left twirls vehicle as motors turn opposite directions. In between stick positions completely proportional. Plugs in like a servo to your Futaba, JR, Hitec, or similar radio. Compatible with gyro steering stabilization. Various volt and amp sizes available. The RDRF47E 55V 75A per motor unit pictured above.
www.vantec.com

VANTEC Order at
(800) 882-6832

Then and Now — A Decade Later With Richard Stuplich

● by Kevin M. Berry

We continue our series of articles about famous figures from a decade ago. The year 2002 marked the ending of the popular Comedy Central series, *BattleBots™*. The year 2003 inaugurated a new era in combat robotics, where our sport left the spotlight and tried to fly on its own.

Grassroots events sprung up everywhere, as documented in our 2012 series of articles, "The History of Robot Combat." For 2013, we're taking a more personal approach, interviewing media stars from that time.

Richard Stuplich first came to the public's attention in the final two seasons of *BattleBots*. His super heavyweight, New Cruelty, was eight wheels and 220 pounds of rock solid battering ram. He reached the finals in Season 4.0, fighting Toro in (arguably) one of the best nationally televised fights ever.

The episode featuring that fight was the first time I'd ever seen the sport. Right at the end of the fight after his bot was dead, Dick made robot combat television history by screaming at his opponent, Reason Bradley, "Hit it again! Hit it again!" That moment epitomized the whole sport for me and is one of the most classic film bites from the series. (You can watch it at Battlebots: Toro vs. New Cruelty Finals Season 4.0 www.youtube.com/watch?v=FzMJvlseDew.)

The next major event — a post-BattleBots pop-up — was held in Orlando in January 2003. Robocide:

The Showdown in O-town, was just a few months later, and the opening fight featured a rookie team fighting with (not very arguably) the worst lightweight bot ever built. After a day of wandering the pits, meeting all the TV personalities and famous bots, I stood next to Dick, facing (also not very arguably) one of the finest lightweight spinners ever built, and certainly the best in the business at that time.

Sadness ensued. Within about 20 seconds it was all over, except for the steadily slowing spiral of death. Dick leaned over to me and asked: "Are you okay?"

There could only be one answer: "Hit it again!" So he did. It was my proudest bot moment, and my only fight outside the Insect classes. (Check it out ... Chupacabra vs. 2EZ Robocide: The Showdown in O-Town www.youtube.com/watch?v=XzHRSlsiBw8.)

Since that time, I've been to many events with Dick and watched his support for the sport. If he's in the pits, he's helping someone else. If he's on the driver's stand, he's out to win.

We linked up with Dick to get his reflections on a long and productive stint in our sport.

Combat Zone: *It's been a decade since the "glory days" of televised Robot Combat. BattleBots encouraged me and dozens of others to join the sport. You worked your way up from competitor to television regular. Could you give a short version of how you moved*

from the pits to the camera?

Dick: My first exposure to robot combat was seeing the Comedy Central season 2.0 of *BattleBots* that aired in December 2000. At that time, I didn't own a hand drill but I was fascinated by the concept of building remote controlled machines that fought each other. It became something of an obsession. What I decided to do was learn the basics and take my time. I bought a welder, hand tools, a drill press, and found a friend who worked as an AutoCad™ drafter to get a crash course in design.

Being from Wisconsin, the idea of driving to California to lose in the first round of a single elimination robot tournament was not interesting to me. I built a complete version of my super heavyweight, New Cruelty.

What I decided to do was skip *BattleBots* 3.0 and head to a local Midwest event called "Twin City MechWars." New Cruelty had problems but was able to win first place, knocking out all opponents but one.

After that, I was hooked and made two more complete revisions before *BattleBots* 4.0. During the *BattleBots* 4.0 season, I was able to do very well, defeating all but the final opponent, taking second place in an event with well more than 400 bots entered. I was happy my parents, wife, and children could make the trip and experience it with me.

When it came time for *BattleBots* season 5.0, I was slightly disappointed at the "seeding" system

that put veterans through into the TV rounds. I talked with production and requested to be inserted into the normal brackets but they refused. I took third at that event, losing to an opponent I had defeated the season before. They had made strategy changes and were ready for a rematch.

Combat Zone: *Was it a huge disappointment to you when the show was cancelled and the sport slipped back into smaller and smaller events?*

Dick: I was disappointed that the days of the huge mega events seemed to be over. The BattleBots pits were something to behold with 400+ teams all working on robots. It was an event that I think will never be duplicated.

Combat Zone: *Because I've always noted your bent to helping others before and during events, I wanted to put in a couple questions about that.*

Were things as sportsmanlike in the BattleBots pits as I've always found them to be at other events I've attended around the country?

Dick: I think they would have been. The size and scope of the event meant that most builders wouldn't even interact. I remember "Team Mauler" had a hydraulic press and it became common knowledge that they were letting anyone use it to try and bend back bent parts. I would say that the stakes for the top teams — the guys I not so affectionately called "the

untouchables" — made them quite secretive.

I should note that only at BattleBots have I witnessed blatant cheating, and I nearly was in a physical altercation with a team that I was to face next that sent a person over to take up residence in my pits and would not leave or move to give me room to work. I beat them handily an hour later. I brought the incident to the attention of BattleBots and I was told, "We know. It's okay. Don't worry about that."

Combat Zone: *Tell us your favorite story about the fabled sportsmanship competitors show in this sport. What has someone done for you to repay your investment in others?*

Dick: This is common at all events now. From people sharing CO₂ fill stations to competitors giving/selling motors right out of their own robots. This is so normal that it is hard to pick one incident. There is a story I like to tell about a boy going to his first event, though.

He was desperate to get the electronics working and was having failure after failure. I told him in a forum, "Bring the bot. I will bring everything you need to make the electronics work." We were able to get his bot working, and after a few events this boy was soon helping others with their bots. We have seen many kids grow to surpass our skills in this sport and in the world. Paul Ventimiglia, for example, has a long resume in robotics now, including

winning BattleBots events and claiming NASA awards in engineering.

Brian Benson also springs to mind. I met him at Robocide in Florida when he was attending his first event with a bot that was, well ... terrible. Today, he has won many events and is a graduate of Worcester Polytechnic and is a mechanical engineer at iRobot.

Combat Zone: *Coollest win? Coolest loss?*

Dick: Probably the coolest loss was to Toro in the finals of BattleBots 4.0. After a massive flip from Toro, the flipper bot, New Cruelty landed on its side and the power switch turned off. We were there for a show so I was screaming "hit it" and then took my controller and slid it across the table to the other team. They went in for a few more flips. It was a great time and good TV!

The coolest win was likely defeating the famed YU812 hammer spinning lightweight with my 60 pound lightweight bar spinner in Florida at an event called Battle At The Beach.

Combat Zone: *So, it's been 10 years. You've done a lot since then. What would you like us to know about your current interests and endeavors?*

Dick: I still build combat robots and have had continued success in nearly all weight classes. My next major event is MotoRama in Harrisburg, PA in February 2014 (www.motoramaevents.com/robots).

Dick: Robot combat is alive and well!

Combat Zone: *Concur! **SV***

Richard Stuplich and his son Alex preparing the first New Cruelty for paint.

Photos courtesy of Richard Stuplich.

Richard Stuplich's 60 pound robot 2EZ (lower) strikes Terry Ewert's two hammer spinner YU812. The blow explodes the hammers on YU812. Photo shows a shower of titanium sparks from the fractured hammer.



Orangutan Drives Fleaweight!

● by Zachary Witeof

One of the challenges when designing a Fleaweight (150 g) robot is finding lightweight components that allow you to squeeze the most out of the limited weight allowance. The electronic components do not necessarily shrink from the Antweight (1 lb) to Fleaweight classes. The typical radio receiver and electronic speed control options for an Antweight are often also used for Fleaweights.

Since this can take up a large portion of the weight allowance compared to an Antweight, I went searching for a lighter option. I found that one option for a speed controller is the B-328 Baby Orangutan microcontroller from Pololu. The B-328 consists of an ATmega328P AVR microcontroller, a dual H-bridge capable of controlling two DC motors at about 1A continuous (3A peak) per channel with 5V-13.5V input, and it weighs in at a paltry 1.5 g without header pins. However, the B-328 requires a little more effort than a purpose-made ESC (Electronic Speed Controller) to implement in your robot.

First, the B-328 needs to be programmed for control of the motors from an RC input using a programming board to connect the board to a PC through USB (you can get the Pololu USB AVR programmer for \$20 at www.pololu.com/catalog/product/1300). Fortunately, Pololu's 3pi robot uses the same microcontroller, so the example code posted by Pololu for the RC 3pi can be used to program the B-328 for our purposes, as well (www.pololu.com/docs/pdf/OJ37/rc_3pi.pdf).

After flashing the program to the controller, I removed the programming pins to save additional weight. Next, to connect the B-328 to an RC receiver, two servo lead signal wires must be connected to the proper inputs on the controller. To avoid modifying the provided code, one servo signal wire should be connected to pin PD0 and the other to pin PC5 (see **Figure 1** for the pin layout).

One servo lead's ground wire should be connected to the ground on the pin on the B-328 so that the receiver is connected to the common ground. If a weapon ESC's BEC (Battery Eliminator Circuit) is not providing power to the receiver, then one servo lead's power wire should be connected to the Vcc pin on the B-328 pin to tap into the 5V regulated line.

Since I used a 2S LiPo battery, I didn't have any issues, but for a 3S battery the B-328's 5V line could be close to maxed out, depending on how much current your receiver requires; it is definitely not recommended for powering a servo directly from the receiver.

The motor leads need to be connected to the M1 and M2 A/B pins. Ensure each motor's positive and negative

terminals are kept consistent with A and B to avoid having to resolder or requiring additional radio programming. Finally, the battery leads should be connected to the Vin and ground pins. You now have a simple, lightweight dual motor controller for \$20 (plus the cost of the USB programmer).

I used the B-328 to control two Pololu 10:1 micro metal gear motors per side on a 2S battery on my Fleaweight wedgebot Chairman Meow over multiple competitions before it failed due to a locked up motor.

With the battery and servo leads (including battery and motor plugs), the completed controller weighs just 7.5 g (**Figure 2**). I could have likely reduced that further. If you want to have a spare on hand, remember to program it and attach the necessary servo, motor, and battery leads prior to a competition to minimize swap time. The B-328 would be an excellent option for Fleaweights with active weapons whose motors aren't expected to be highly stressed. **SV**



FIGURE 1.
Photo courtesy of Pololu.

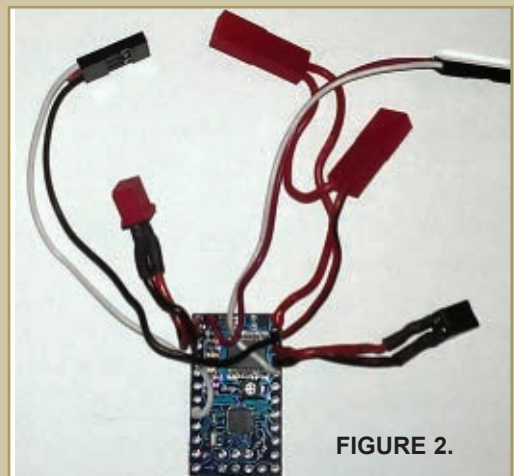


FIGURE 2.

PRODUCT REVIEW:

Botbitz 30A ESC

● by Zachary Witeof

The Banebots BB-12-45 was for many years the most commonly used speed controller in the 12 lb Hobbyweight class of combat robot. They were compact, simple to use, and reasonably reliable. I had used them successfully on my 3 lb Beetleweight wedge/brick Trilobite, and had planned to use them on my fleet of mini bothockey bots.

However, when I came to order them I found they were no longer available. Looking around, I found that Botbitz (www.botbitz.com; an Australian company) had a new 30A ESC (Electronic Speed Controller) that looked suitable.

They cost \$45 USD including shipping. I received mine within two weeks of the order.

Botbitz reprograms non-

reversible Hobbyking ESCs designed for aircraft into reversible ESCs suitable for drive on a combat robot. The 30A model is based on the Turnigy Multistar ESC and will operate on two 6S LiPo (6V-24V) batteries.

Note that you cannot use the Turnigy programming card with the Botbitz ESC.

The ESC at 3" x 1" and 3/8" thick is about twice the size of the Banebots 12-45, but it does have a nominal rating more than twice as high. It weighs 1.4 oz by the time you have trimmed the leads and added connectors.

I tested it in an 8 lb chassis that uses two HarborFreight drill motors to provide 4WD, and used a 6S LiFe battery pack. The radio used was a HobbyKing HK6S.

The Botbitz ESCs don't have

any LEDs to indicate whether or not you have a signal, but they powered up without a problem (apart from perhaps being a little fussy to trim them, to not operating with the stick in neutral).

They had a nice smooth response curve and the bot proved easy to drive with them. They failsafe correctly for combat robotics, shutting down quickly after the transmitter is turned off.

The Botbitz BB-30A-ESC is a useful ESC and should find its way into bots from 3-30 lbs. I'll be using them in my mini bothockey bots.

SV



Botbitz BB-30A-ESC.

Motor Controllers • Arduino • Arduino Kits • Arduino Shields • Robot Platforms • Parts

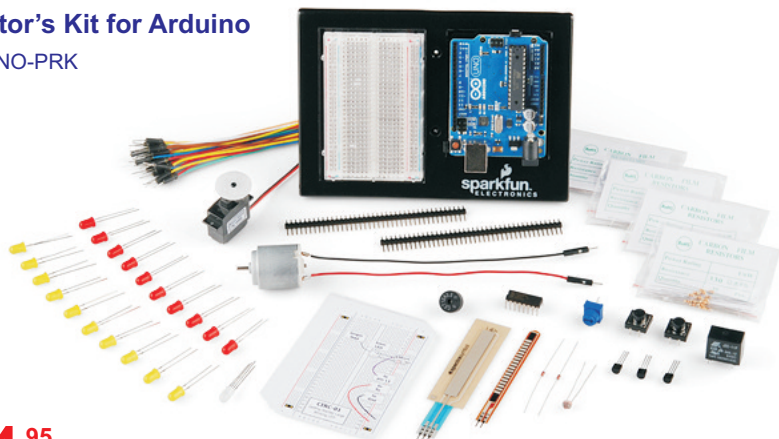
Arduino Uno



\$29^{.95}

ARDUINO-UNO
Latest "R3" Version!

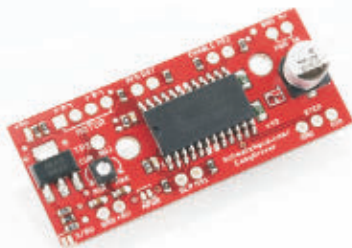
Inventor's Kit for Arduino
ARDUINO-PRK



\$94^{.95}

Includes 36-Page Printed Full-Color Manual

EasyDriver Stepper Motor Driver



SX09402

\$14^{.95}

Stepper Motor



SX09238

\$19^{.95}

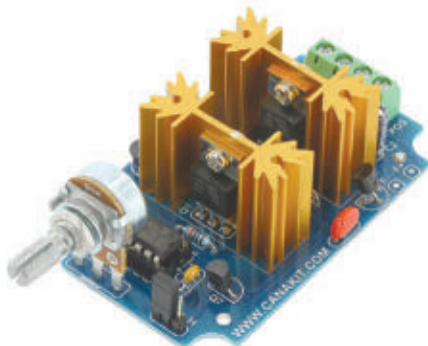
50A Motor Speed Controller (PWM)
UK1133



Optional LCD

\$59^{.95}

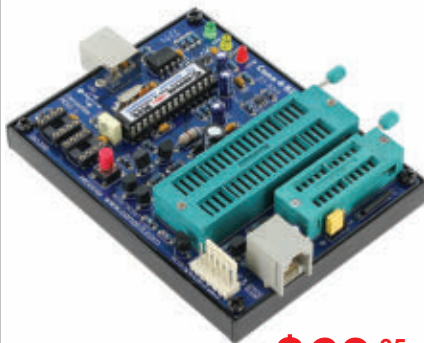
7A Bi-Directional Motor Speed Controller (PWM)



UK1125

\$39^{.95}

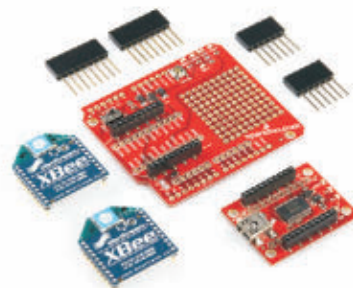
USB PIC Programmer (MPLAB Compatible)



UK1300

\$69^{.95}

Xbee Wireless Kit



XBEE-KIT

\$94^{.95}

3D Printers

This month:

Part 1. Introduction into 3D Printers

Part 2. Assembly Highlights

Part 3. Software and Configuration

Part 4. Tuning

Part 5. Filament

Part 6. Conclusion

by Michael Simpson

Go to www.servomagazine.com/index.php?magazine/article/september2013_Simpson for any additional files and/or downloads associated with this article.

You can also discuss this topic at <http://forum.servomagazine.com>.



Filament is the life blood to a 3D printer. Without it, your printer will not print, and bad filament will create lousy prints. In this article, I will talk about the various types of filament and I will show you how to calibrate the printer to a specific type. While the filament mentioned in this article is available in both 1.75 mm and 3 mm diameters, I will be concentrating on the more popular 1.75 mm version.

Filament Calibration

The 3D printer manufacturer will be able to provide most of the configuration settings for the printer. There are, however, a set of filament-based parameters that you must provide. The makeup of the filament and its true diameter will cause it to extrude at slightly different rates. You must provide a calibrated filament multiplier setting in order to create accurate prints. This setting in Slic3r and Creator is called "Extrusion multiplier."

By default, it is set to a value of one. Our goal is to change this value so that the amount of plastic that is extruded matches what the machine thinks it's extruding. If it extrudes too much, you will get too much filament overlap and solid infills will suffer. Too little, and you will get gaps.

Calibration Setup

You need to do a test print or two to calibrate the filament. For this exercise, I have selected a simple cylinder that is 50 mm in diameter by 5 mm high. We have to change some of the slicer parameters so that only a single outside perimeter is printed. This will allow us to use a set of digital calipers to measure the thickness of the extruded perimeter so that we can calculate the filament multiplier.

Note that you may also use other shapes to print the perimeters. A small square will work just as well. You won't need to print much — just enough to get about 5 mm height on the object, which is about 20 layers.

If you are using Slic3r as your slicer, then set the parameters as shown in **Table 1**.

If you are using Creator, set the parameters as shown in **Table 2**.

Once the settings have been changed, generate the G-code for the object. In Repetier, this is done by hitting the "Slice with Slic3r" button on the slicer tab. Creator uses the "Prepare" button. The generated G-code preview should look like the one shown in **Figure 1**.

Please be sure to post any questions in the *SERVO Magazine* forums at <http://forum.servomagazine.com/viewtopic.php?f=49&t=16968>. I will also be posting additional information on my website at www.kronosrobotics.com/3d.

Slic3r Settings

TABLE 1.

Print Settings Tab	
Layers and Perimeters	Layer height: .25 First layer height: .25 Perimeters: 1 Randomized starting points: Unchecked Solid layers top: 0 Solid layers bottom: 0
Infill	Fill density: 0
Advanced	Set all extrusion width settings to .4 (set to .05 greater than nozzle diameter). This is your target.
Filament Settings Tab	
Filament	Diameter: 1.75 Extrusion multiplier: 1
Printer Settings	
Extruder	Nozzle diameter: .35 (set to actual nozzle diameter)

Creator FFF Settings

TABLE 2.

Extruder Tab	Extrusion diameter: .35 (set to actual nozzle diameter) Auto extrusion width: Unchecked Value: .4 (Set to .05 greater than nozzle diameter) This is your target. Extrusion multiplier: 1
Layer Tab	Layer height: .25 Top solid layers: 0 Bottom solid layers: 0 Outline/perimeter shells: 1
Infill Tab	Infill percentage: 0
Other Tab	Filament diameter: 1.75

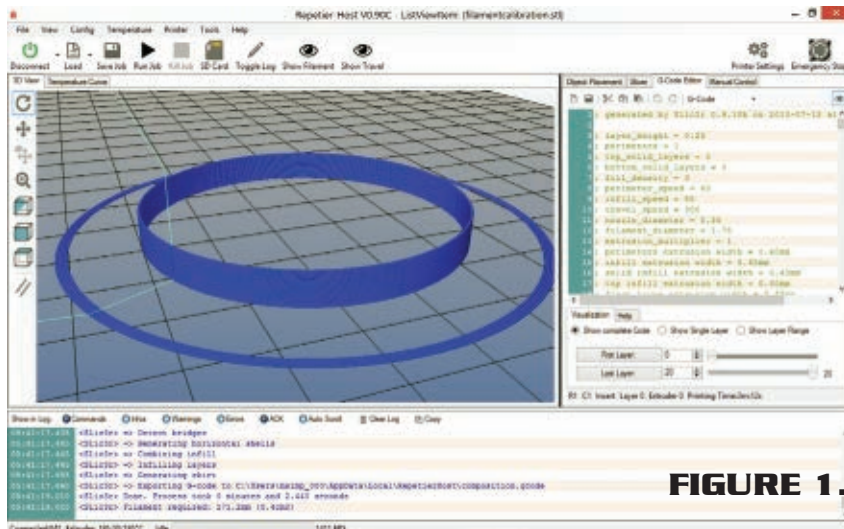
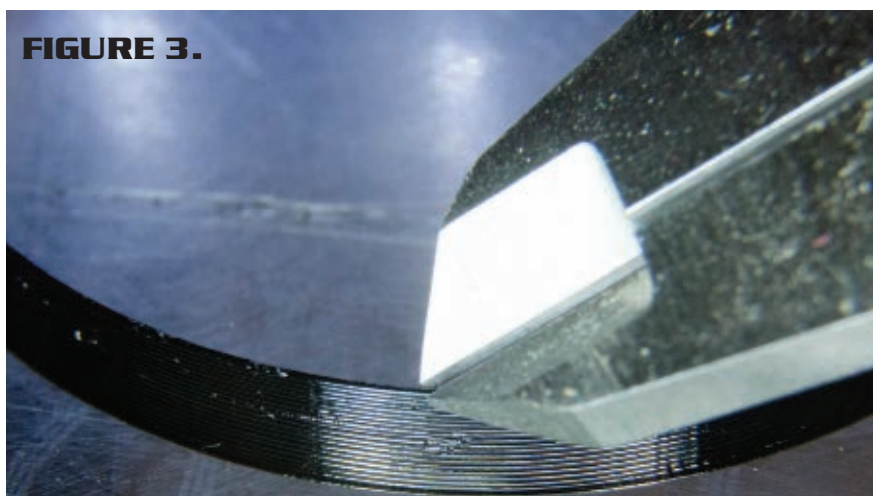
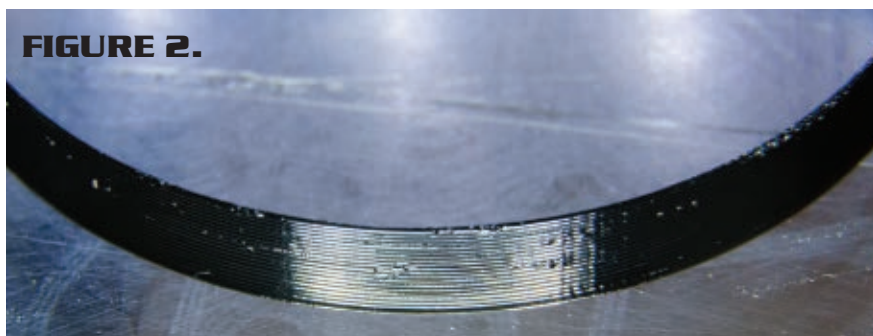


FIGURE 1.

Heat your extruder, then start the print once the extruders target temperature is reached. For new PLA, start out at 185 degrees Celsius; for ABS use 230 degrees Celsius. Adjust as needed. When the print is complete, it will look like the one shown in **Figure 2**.



Since you are calibrating the filament, there's a good chance that the print will be far from perfect, so pick a smooth spot and use a set of digital calipers to measure the thickness of the last layer printed (**Figure 3**). The goal is to measure only a single layer. Measure at several points

around the object. It's very easy to get readings over the actual printed thickness. If you measure more than one layer, it will show a thicker reading. I squeeze the calipers with a good deal of force when I take my readings.

In my example, the measured thickness was .37 mm (**Figure 4**); the target was .4 mm. To get your multiplier, divide your target by your measured thickness. In this example, I will use an extrusion multiplier of 1.08. Plug this value into the Extrusion multiplier field and do another print.

Your measured value should match your target value. That's pretty much how you calibrate your filament. To make things easier to set up when calibrating filament, keep a set of saved configuration settings just for calibration.

ABS vs. PLA

In the past couple years, several types of filament have emerged. ABS, PLA, PVA, nylon, polycarbonate, and even some liquid MDF materials are starting to show up. By far, the two most popular are ABS and PLA. They each have their own strengths, weaknesses, and printing requirements, but first let's talk about why you might use one over the other.

ABS Warping

ABS shrinks as it cools. When the bottom layers of the print cools while we are still printing on the top layers, we get warping. The larger the print, the worse the warping.

There are two ways to minimize the warping: a heated bed and brute force. A bed heated to about 100 degrees Celsius will reduce the warping on larger prints but won't eliminate it. On smaller prints with good adhesion, the warping will be unnoticeable. On larger prints, the force of the warping will pull the print away from the bed as shown in **Figure 5**.

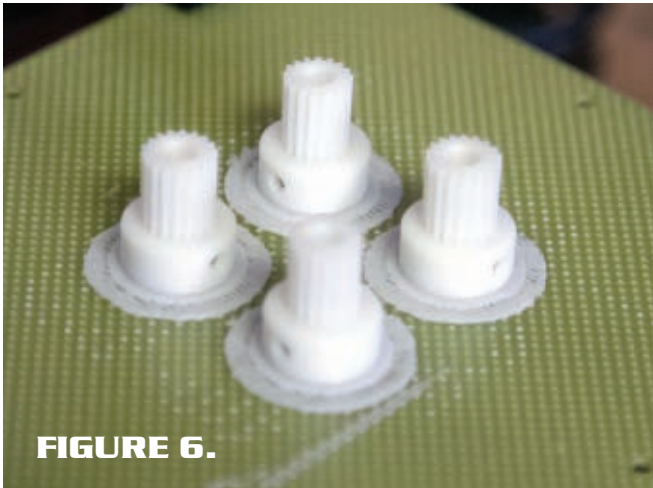


FIGURE 6.

Bed adhesion is super critical when printing with ABS since some printers use a brute force method in order to overcome warping. The Afinia uses a perforated board with a thick wide raft brute force approach. The first layer of the raft is printed very thick and will sink into the small perforated holes. Thinner interface layers are then printed,

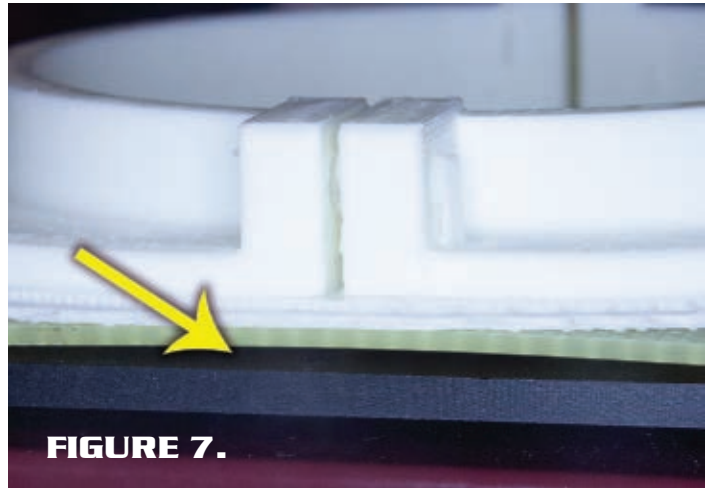


FIGURE 7.

then finally, the part itself. This method is extremely effective on small prints like those shown in **Figure 6**. On larger prints, however, the warping can transfer itself to the perforated board as shown in **Figure 7**.

ABS Smell

To put it frankly, ABS stinks as it is printed. While quick small prints are not so much of a problem, doing a large print can stink up your house.

ABS Bed Adhesion

If you are not using an Afinia 3D printer, the best way to get ABS to stick to the heated bed is with Kapton tape. Kapton tape comes in rolls like those shown in **Figure 8**. The tape is placed on the heated bed in strips. **Figure 9** shows an 8" x 10" piece of glass with five strips of 2" tape applied to it. The glass is then placed on a heated bed (in this case, a MakerGear M2) and heated to 110 degrees Celsius as shown in **Figure 10**.



FIGURE 8.

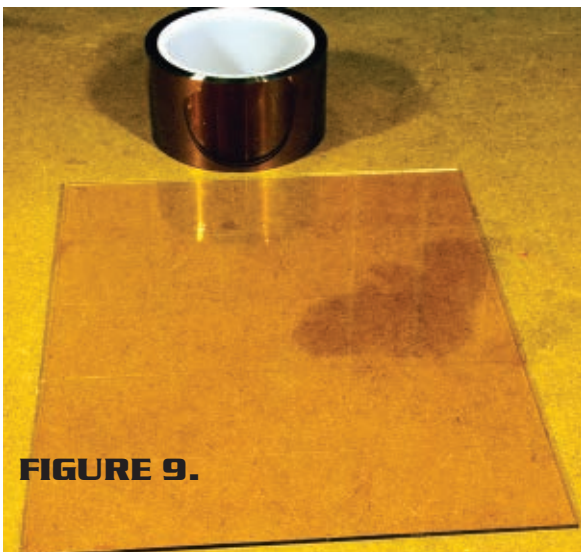


FIGURE 9.

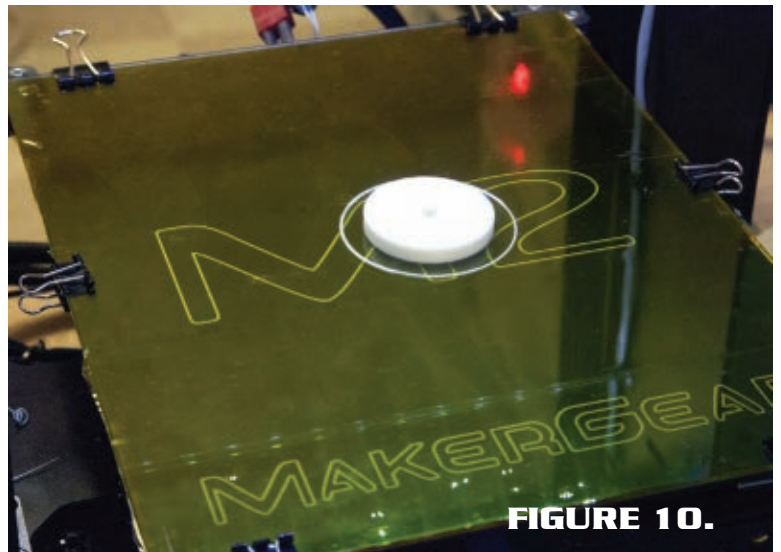


FIGURE 10.

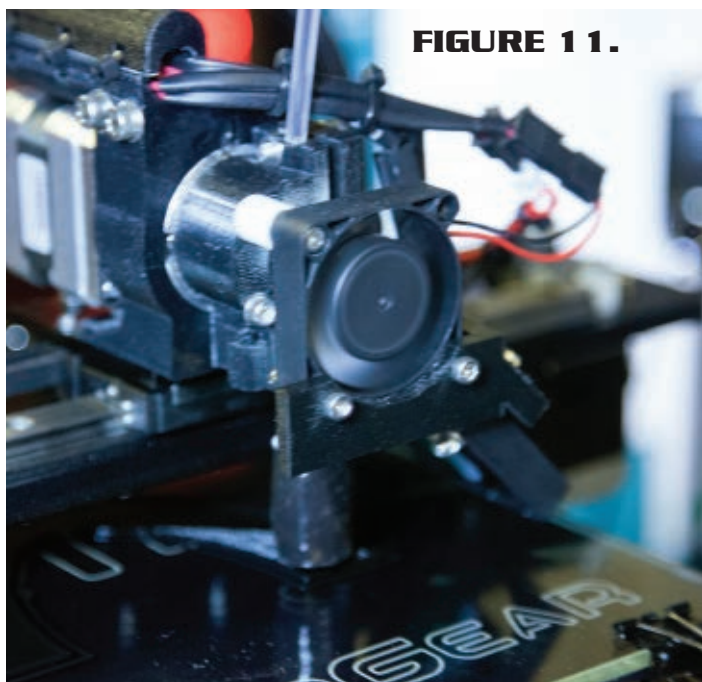


FIGURE 11.

The down side to using Kapton tape is that it can sometimes be difficult to remove the finished print, and damage to the Kapton tape can occur. If you do damage the tape, you will need to replace it.

Note that some objects can be printed on blue painter's tape. It does not have the adhesion that Kapton does, but it can work in a pinch.

PLA to the Rescue

Okay. Now you understand some of the downsides of

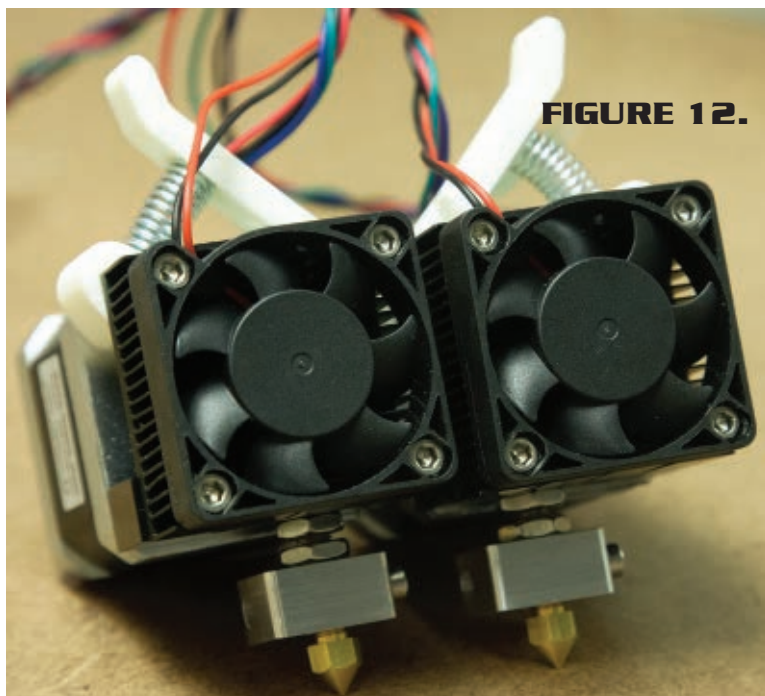


FIGURE 12.

printing with ABS. What are our alternatives? The answer is PLA which is a bio-degradable plastic made from corn or other plants. It warps very little and does not smell as bad as ABS. Corn is used in US-made PLA, but since other plants may be used on imported PLA, the properties may vary considerably.

PLA Melting Point

PLA has a lower melting point than ABS and so it prints at a lower temperature than ABS. This lower melting point is one of the major disadvantages of printing with PLA. As PLA is printed, the heat from the extruder nozzle can creep up the extruder and soften the filament as the print progresses. This softening can cause the filament to jam inside the extruder.

To solve the jamming problem, a fan like the one shown in **Figure 11** can be used to keep the filament from getting soft inside the extruder. **Figure 12** shows a set of cooling fans used to cool the filament in a dual extruder.

PLA Caramelization

Unlike ABS, PLA cannot be left with the extruder heated for any length of time without extruding filament. When heated for short periods of time without extruding, PLA will caramelize. This action will clog the extruder nozzle.

PLA Bed Adhesion

I have found PLA to stick reliably to three surfaces: glass heated to 65-75 degrees Celsius; Kapton heated to 65-75 degrees Celsius; and unheated acrylic. That's not to say it won't stick to other surfaces; it's just that these are my top three.

PLA sticks best to unheated acrylic. I like to use a fine sanding sponge to scuff the surfaces as shown in **Figure 13**. Try not to use solvents like alcohol on acrylic or it may start to chip and crack like the sheet shown in **Figure 14**.



FIGURE 13.



FIGURE 14.

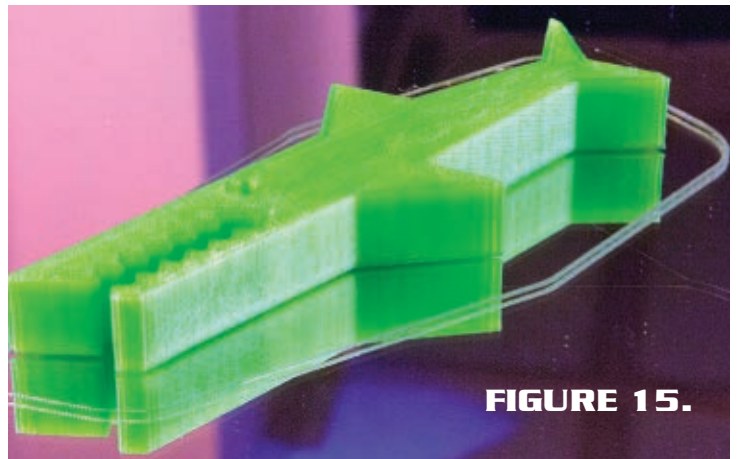


FIGURE 15.

The problem when printing on acrylic is that it can be difficult to remove large prints. When printing on glass or Kapton (like the one shown in **Figure 15**), the print will stick at about 65 degrees Celsius. Once cooled, it can easily be pulled free.

It is important to mention here that the pigment used in some PLA can affect its ability to stick to heated glass or Kapton. For example, I have some white PLA that will only stick to unheated acrylic.

Structural Differences Between PLA and ABS

ABS is much more flexible than PLA. It can be used to print flexible items like the stretch bracelet shown in **Figure 16**. This item — while flexible when printed in ABS — would be too brittle when printed in PLA.

The frame for the quad shown in **Figure 17** was printed in PLA. If this were printed in ABS, the arms would be too flexible. PLA is much stiffer and works perfect in a situation when flexibility is a disadvantage.



FIGURE 16.



FIGURE 17.

LINEAR SERVOS



L12-R Linear Servo

- Direct replacement for regular rotary servos
- Standard 3 wire connectors
- Compatible with most R/C receivers
- 1-2ms PWM control signal, 6v power
- 1", 2" and 4" strokes
- 3-10 lbs. force range
- 1/4" to 1" per second speed ranges
- Compatible with VEX



L16 Linear Actuators

- 2", 4" and 6" strokes
- 10 - 40 lbs. force range
- 1/2" to 1" per second speed ranges
- Options include Limit Switches and Position Feedback

New!

PQ12 Linear Actuator

- Miniature Linear Motion Devices
- 6 or 12 volts, 3/4" stroke
- Up to 5 lbs. force
- Integrated position feedback or limit switches at end of stroke
- External position control available



Linear Actuator Controller (LAC)

- Will drive any Linear Actuator with position feedback
- Up to 24v and 4 Amps
- USB connectivity to drive the actuator with your computer
- Adjustable speed, limits and sensitivity



L12-NXT Linear Servo

- Designed for LEGO Mindstorms NXT®
- Plugs directly into your NXT Brick
- NXT-G Block available for download
- Can be used with Technic and PF
- Max. speed: 1/2" per sec.
- Pushes up to 5 lbs.
- 2" and 4" strokes



Available Now @
www.firgelli.com

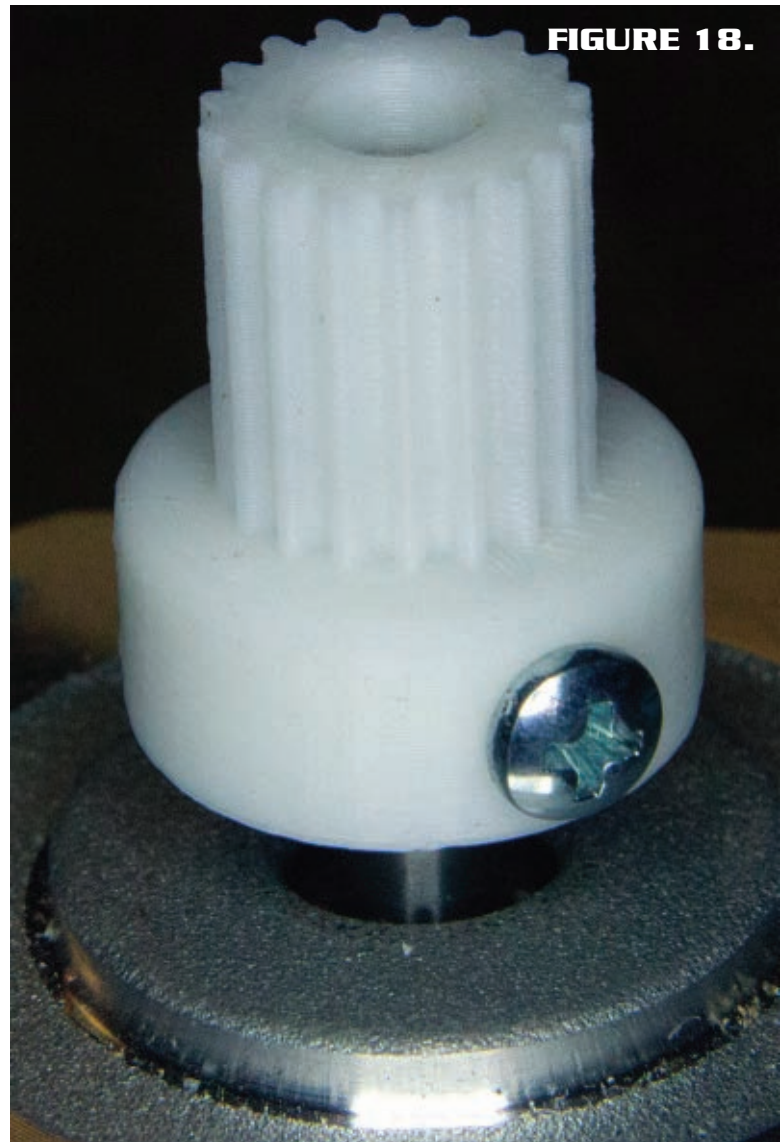


FIGURE 18.

ABS tends to print finer details than PLA. It also has a slightly smoother finish than PLA. The GT2 gear shown in **Figure 18** could not be printed in PLA, but it does print very well in ABS.

Final Thoughts

It is important that you select the correct filament for the printed object. Some objects will work equally well with both PLA and ABS, while others are better suited to one or the other.

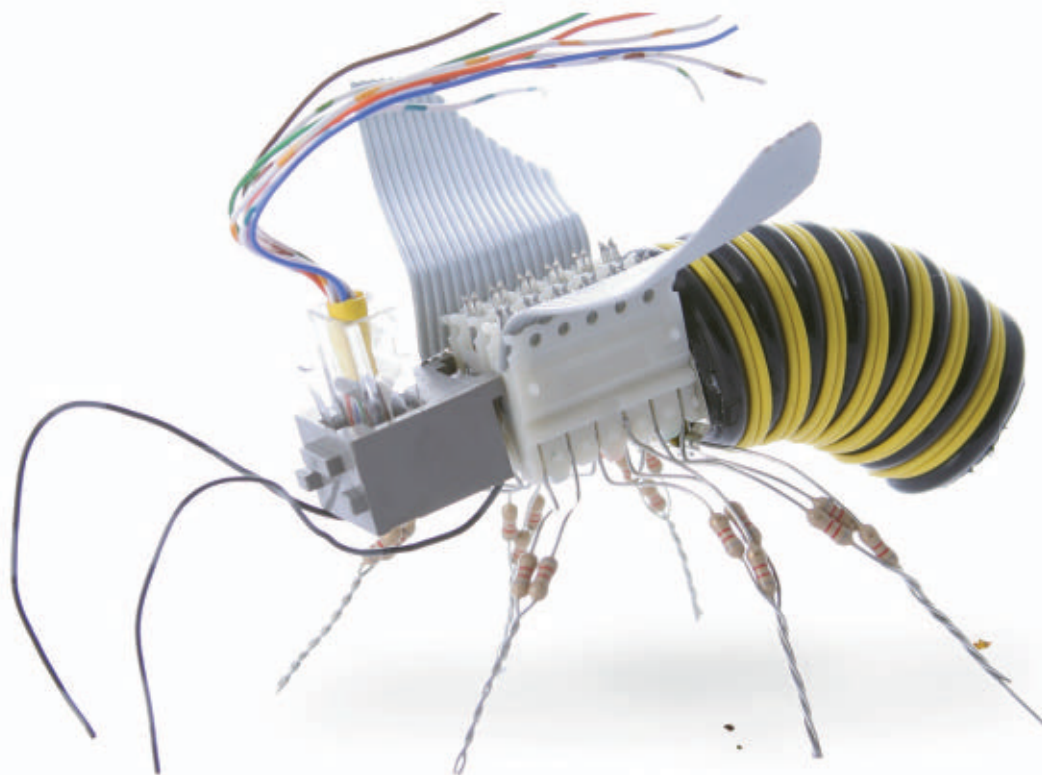
Many 3D printer manufacturers are selling 3D printers without a heated bed and state they are PLA

printers. By purchasing a printer with a heated bed, you will broaden your ability to print other materials. You also will gain the ability to print PLA on other media like glass and Kapton tape.

In addition, there are extruder settings for setting up and calibrating your extruder. These settings will be provided by the manufacturer, but feel free to tweak them as you see fit.

Next Month

I will tie up the loose ends and give you my final thoughts on the printers mentioned in this series. **SV**



GENUS: WASPUS ROBOTIUS

DESIGN MACHINES THAT FLY IN THE FACE OF PAST LIMITATIONS.

The evolving field of robotics is growing fast. It requires creative and innovative thinkers with a sound education in cutting edge advancing technology.

Start a life of innovation with a degree in Robotics and Embedded Systems from UAT.



uat.edu/robotics

Advancing Computer Science > **Artificial Life Programming** > Digital Media > Digital Video > Enterprise Software Development > Game Art and Animation > Game Design
Game Programming > Human-Computer Interaction > Network Engineering > Network Security > **Open Source Technologies** > **Robotics and Embedded Systems** > Serious Game and Simulation
Strategic Technology Development > Technology Forensics > Technology Product Design > Technology Studies > Virtual Modeling and Design > Web and Social Media Technologies

Please see www.uat.edu/fastfacts for the latest information about degree program performance, placement and costs.

A Look at Holonomic Locomotion

by Roger Tang
and Dick Swan

Holonomic robots are omnidirectional robots that can move in any direction from any orientation, creating an incredibly mobile robot. So, it's easy to move the robot in a congested area. A four wheel drive (4WD) omnidirectional robot can be built using either mecanum wheels or omniwheels. Both wheel types are similar in that they have rollers mounted around the wheel's circumference allowing for sideways movement of the robot. The difference between the two types is the angle at which the rollers are mounted at. This article looks at omnidirectional robots constructed with both types of wheels and includes software code for providing this control. The robots are constructed using the VEX Robotics building system.

VEX mecanum wheel (side view).



VEX omnidirectional wheel.



Mecanum Wheels

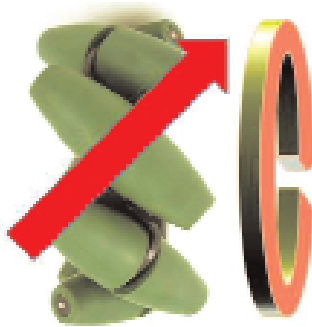
How It Works

Mecanum wheels are very unique looking. Each wheel has rollers offset by 45 degrees from the wheel and the drive train. This causes the motors to introduce force at 45 degree angles. Different combinations of force vectors can combine/cancel to produce movement in all directions.

This means that running all wheels in the same direction will result in a forward or backwards direction; running one side in the opposite direction of the other will result in rotation; and running the wheels on one diagonal in the opposite direction of the other diagonal will result in sideways movement.

When putting on mecanum wheels, the rollers of the wheel should create an X when viewed from the top. Meanwhile, on the bottom the rollers should create a diamond. This is an important rule to follow or else the behavior of the robot will not act as expected.

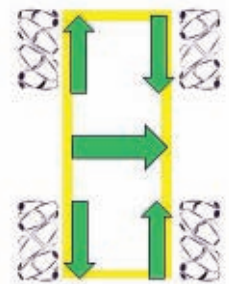
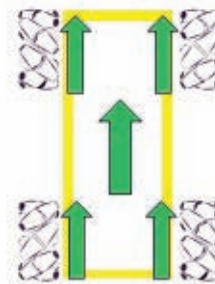
Another important item to consider when using a mecanum drive system is weight distribution and build quality. The mecanum works on the principle of combining and canceling vectors. If the motors cannot match each other, the motion of the robot will not be as expected.



Rotation of a single mecanum wheel provides a "force vector" perpendicular to the rollers. This is the direction that the wheel would want to move.



Mecanum wheels are mounted on a 4WD robot as shown. Note the orientation of the rollers. Two of the wheels are mounted with the rollers at +45 degrees and two with rollers oriented at -45 degrees.



```
task main()
{
    int Y1, X1;           // Vertical, Horizontal Joystick Values
    int rotation;         // Rotation Joystick Values
    int deadband = 20;    // Threshold value for deadzone

    while (true)
    {
        // Get value of three joysticks used for speed and
        // direction.
        // Other platforms may have different code for this.

        Y1 = vexRT[Ch3];   // Vertical axis
        X1 = vexRT[Ch4];   // Horizontal axis
        rotation = vexRT[Ch1]; // Rotation axis

        // Implement dead zones to compensate for joystick values
        // not always returning to zero

        if (abs(Y1) < deadband)
            Y1 = 0;
        if (abs(X1) < deadband)
            X1 = 0;
        if (abs(rotation) < deadband)
            rotation = 0;

        // Convert joystick values to motor speeds

        motor[frontRight] = Y1 - X1 - rotation;
        motor[backRight] = Y1 + X1 - rotation;
        motor[frontLeft] = Y1 + X1 + rotation;
        motor[backLeft] = Y1 - X1 + rotation;
    }
}
```

Source Code

The source code to control the robot is amazingly simple. The complete program is barely 20 lines of code. Since joysticks do not always return exactly to the center value of zero, a small dead zone is used to treat all values close to zero as zero.

The actual power applied to each of the four motors is a simple formula of the three joystick axes.

The software was written in ROBOTC – a dialect of the popular C programming language optimized for use with robots.

If you're building your own robot, you may find that one or more motors move in the opposite direction than intended. You can change this by reversing the two wires to the motor. Or, with ROBOTC, there's a command (not shown) to have software implement a motor direction reversal.

A couple of notes on the code. In ROBOTC, the joystick axes have a range of -127 to +127; other products may provide a range of 0 to 255 or 0 to 1023. In ROBOTC, motor power levels also range from -127 to +127; other systems may use a different scale. If you're building for a different platform, you may have to adjust accordingly for these factors.



User Interface

A remote control was used to drive the robot using an "arcade style" control. With arcade style control, the horizontal and vertical axes of a joystick specify the speed and direction of the robot. The horizontal axis of a second joystick controls the rotation of the robot.

Omniwheels

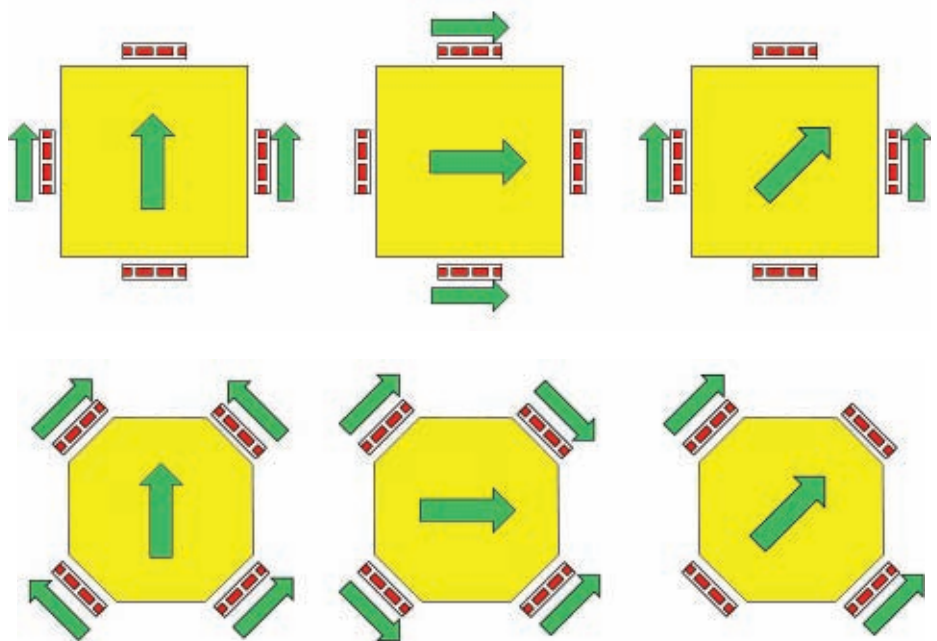
How It Works

Omniwheels have small rollers around their circumference that are perpendicular to the rolling direction. The result is a wheel that can roll like a normal wheel but also slide laterally very easily. Therefore, the wheels cannot be mounted in the same manner as the aforementioned mecanum wheel.

The simplest design to understand is a robot with a square base with the wheels situated in the middle of each side. However, while simple, if a force were to be directly applied to one of the corners of the square, two of the wheels would be lifted up. Also, I don't want to damage my walls by banging a pointy corner of a robot into them. Finally, squares are rather dull. Don't be a square.

With the square design off the drawing table, I tinkered with the idea of lopping off the corners of the square to create an octagon. I liked it. It solved the weight distribution and pointy corners issue. Also, an octagon isn't as dull. The octagon shape has a significant advantage in powering the robot. If there's a wheel on each side, going forward only has two motors powered. With the motors at each corner, going forward uses all four motors.

Notice that this runs on the same idea as a mecanum wheel. The wheels are situated at 45 degree angles and create a similar system of combining /canceling force vectors. In smaller robots, the difference between omniwheels and mecanum wheels is miniscule. In larger applications, however, there are different places of stress on the drive system.



The Interface

Omniwheel robots can use the same joystick control as the one for mecanum wheels. The same software also works with omniwheels.

Construction

VEX Robotics Design System – Metalwork

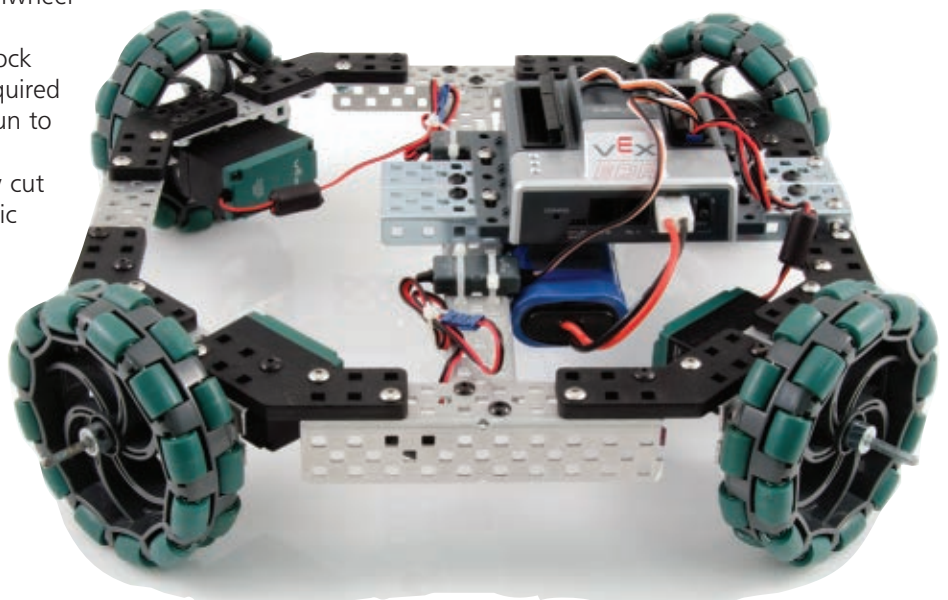
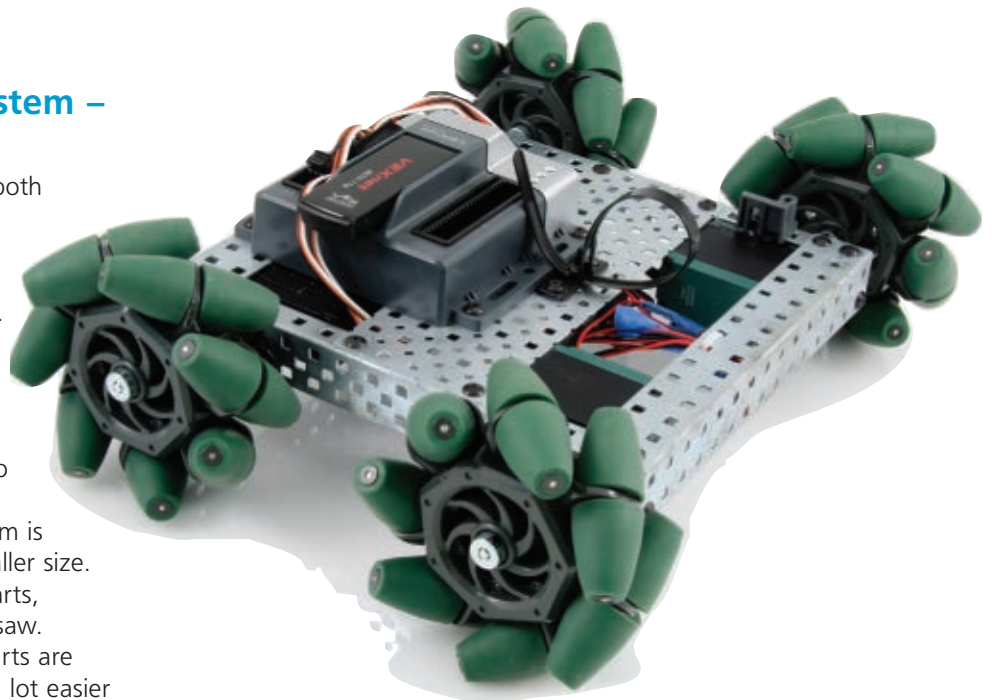
It was a simple job to fabricate both types of robots using parts from the VEX Robotics Design System. This is due to the simplicity and customization that the system offers. It was quite easy to assemble the square base with the numerous available building parts. Standard size parts were used.

The omniwheel robot was not so simple. It required 45 degree angles and custom length beams. The system is designed for cutting beams to a smaller size. However, using the standard steel parts, this can take some time with a hacksaw.

Fortunately, many of the VEX parts are also available in aluminum which is a lot easier to cut. Aluminum was used for the omniwheel robot.

You'd have to trim and bend the stock parts to create the 45 degree angles required for the omniwheel robot. It was more fun to design custom ABS plastic connectors instead; once designed, they were easily cut on a laser cutter. They're the black plastic parts in the photo.

Once built, the frame is very rigid and almost indestructible. The drawback is that it requires lots of nuts and bolts which are time-consuming to tighten, and often seem to be in cramped corners where it's difficult to manipulate the tightening wrenches.





VEX IQ

A second omniwheel robot was also built using the recently released VEX IQ system. This system is similar to the VEX Robotics Design System except in plastic. This system comes with a selection of 30, 45, 60, and 90 degree connectors. The octagonal base was easily constructed from stock parts.

The construction process was much faster. There are no nuts and bolts; the plastic beams are quickly joined together with plastic pins that snap into both beams.

The wiring was also simpler. Motors connect to the brain with cables containing a modified style of the jacks

used with telephones. The rechargeable battery slides into the base of the brain.

The VEX IQ motors are really neat. They have integrated high resolution encoders (960 counts per wheel revolution). An embedded CPU in the motor is used to provide precise speed and position control of the motor. This CPU uses feedback from the motor to precisely regulate the motor's speed. Our simple application here didn't need this functionality, but it will be used in an upcoming article covering dead-reckoning navigation.

What's Next

These projects were very simple and easy to learn. The VEX Robotics Design System is a great system for strong, durable robots and the ROBOTC integrated development environment makes this platform viable for just about all your robotic ideas. The new VEX IQ system is another very easy and flexible system that gets rid of the somewhat tedious nuts and bolts construction. The \$249 list price makes this system very attractive.

This article gives just a basic test for omnidirectional drive systems. There are more advanced ways to control an omnidirectional-based robot. For instance, there are videos of mecanum robots moving in a direction while spinning. While how to do this is beyond the scope of this article, it makes a good exercise if you feel like challenging yourself.

Another challenge could be trying to implement dead reckoning — especially with the integrated wheel encoders in the new VEX IQ system.

All the robots constructed here used four wheel drive. The same principles could be used to construct a robot with three wheels. The motors would be positioned at the corners of an equilateral triangle. The control algorithm could be quite complicated as it will involve trig functions which can be messy on some microcontrollers. **SV**

Go to www.servomagazine.com/index.php?/magazine/article/september2013_Swan for any additional files and/or downloads associated with this article. You can also discuss this topic at <http://forum.servomagazine.com>.



AP CIRCUITS
PCB Fabrication Since 1984

As low as...

\$9.95
each!

Two Boards
Two Layers
Two Masks
One Legend

Unmasked boards ship next day!

www.apcircuits.com



**DIY NEVER
HAD A BETTER
FRIEND...**

Take your DIY project to the next level with PanaVise work holding tools. Perfect for hobbies, soldering, electronics, crafting & repair, PanaVise tools have hundreds of uses only limited by your imagination.

PanaVise, "better than a third hand!"



PANA VISE
Innovative Holding Solutions

Now available at



Model 301
640-0178



Model 324
640-0177

www.radioshack.com/StoreLocator

Making Better Arduino Robots

By Gordon McComb

FIGURE 1. The ArdBot II, ready to rumble.

with the ArdBot II

Part 2

Everyone wants a robot to serve them drinks and pick up their socks. Yet, despite how mundane such tasks may sound, these chores require a sophisticated robot costing more than the average automobile. The sensors and programming required to discern old socks from sleeping cats requires extensive computing power, not to mention considerable skill on the part of the programmer.

Your first robot doesn't have to be a mimic of C-3PO. It's better to start small, and grow your robots as you gain experience. The ArdBot II is designed for simpler tasks, so it requires only a small body, inexpensive sensors, and a \$30 brain.

Last month, you learned how to construct the mechanical chassis of the ArdBot II.

This month, we'll move forward with completing its electrical subsystems, and giving the robot its first taste of adventure by programming it with a simple servo test routine.

Mounting and Wiring the Breadboard

As noted in the previous installment, the ArdBot II uses an Arduino Uno board mounted on the robot's top deck. A separate mini breadboard is stuck into place nearby, and serves as a convenient place to plug in circuits to complete the robot's wiring. Part of this wiring encompasses the power and signal lines for the two servo motors. The completed ArdBot II robot is shown in **Figure 1**.

Most mini breadboards come with double-sided tape already stuck to them; just peel off the liner and place it where you want it. The exact mounting location of the breadboard isn't super critical, except it should be more or less as positioned in **Figure 1**.

Figure 2 shows where to attach the ArdBot II's left and right servo motors to the breadboard. To make it easier to interconnect things, use three breakaway male header pins inserted into the breadboard. Each set of headers should contain three pins. The design of these allows you to snap off the number of pins you need.

You want the so-called "double-long" pins, so insert them into both the breadboard and the female headers from the servo and the 4xAA battery pack. (Refer to last month's article for how to wire the female header to the battery leads.)

Note that one of the pins for the battery header is clipped off; again refer to Part 1 for the details. After carefully clipping off this pin, insert it into the unused plug of the battery connector. The broken pin will help prevent you from attaching the battery connector backwards which could cause reverse voltage to the servos. If this happens, very likely your servos will be instantly and permanently damaged!

With **Figure 3** as a guide, use a short length of 22 gauge single conductor jumper wires to complete the breadboard circuitry. Be sure to double-check all the wiring when you're done. You want to avoid wiring mistakes to the servos; flipping black for red – or any color – can also cause irreversible harm to your servos, and possibly your Arduino.

Connections between the breadboard and Arduino can be 3"-4" lengths of solid conductor jumper wire, but I like to use pre-made female-to-female jumpers (see the previous installment for sources) with double-long pins inserted to make

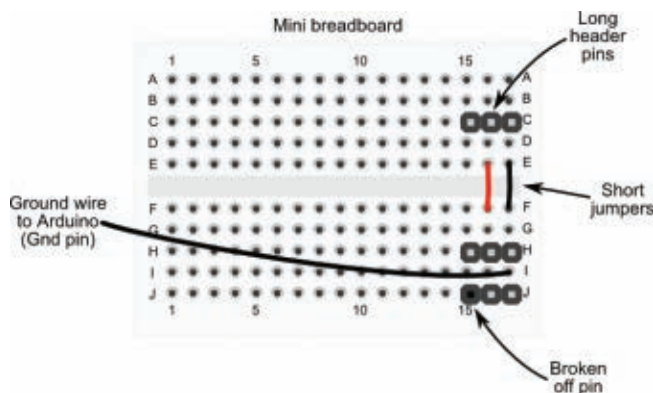


FIGURE 2. The ArdBot II uses a small (so-called "mini") solderless breadboard that serves as an interconnection between the Arduino and external components such as servo motors.

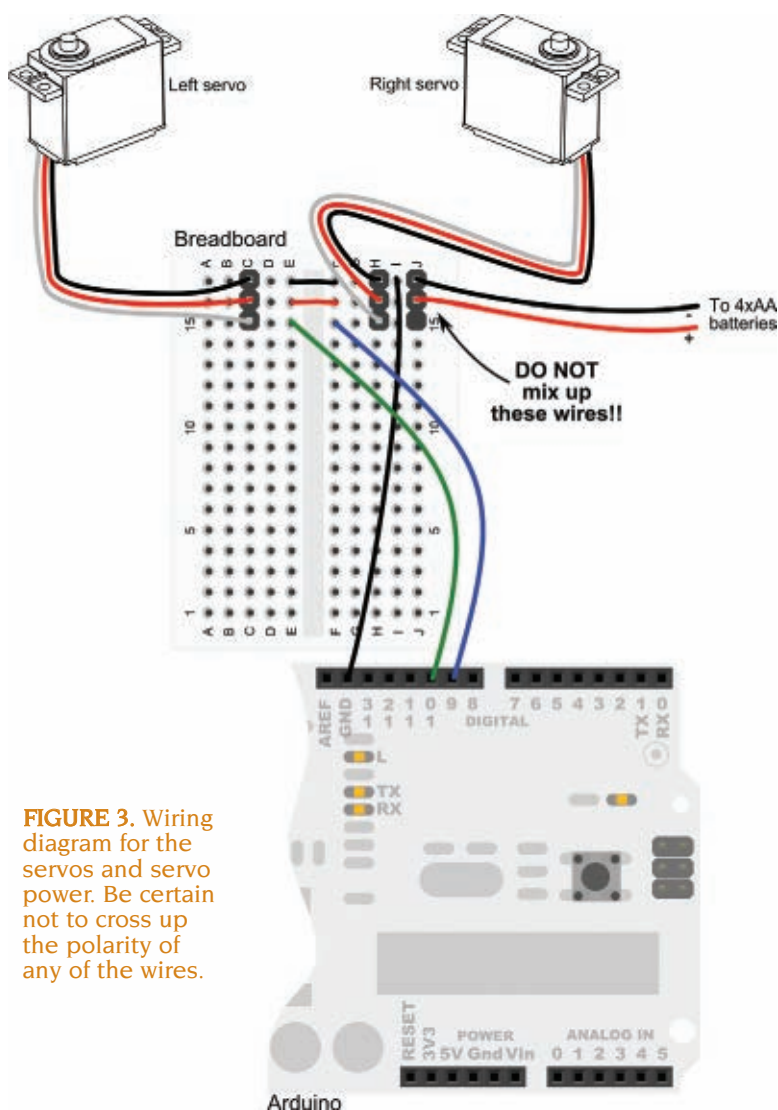


FIGURE 3. Wiring diagram for the servos and servo power. Be certain not to cross up the polarity of any of the wires.

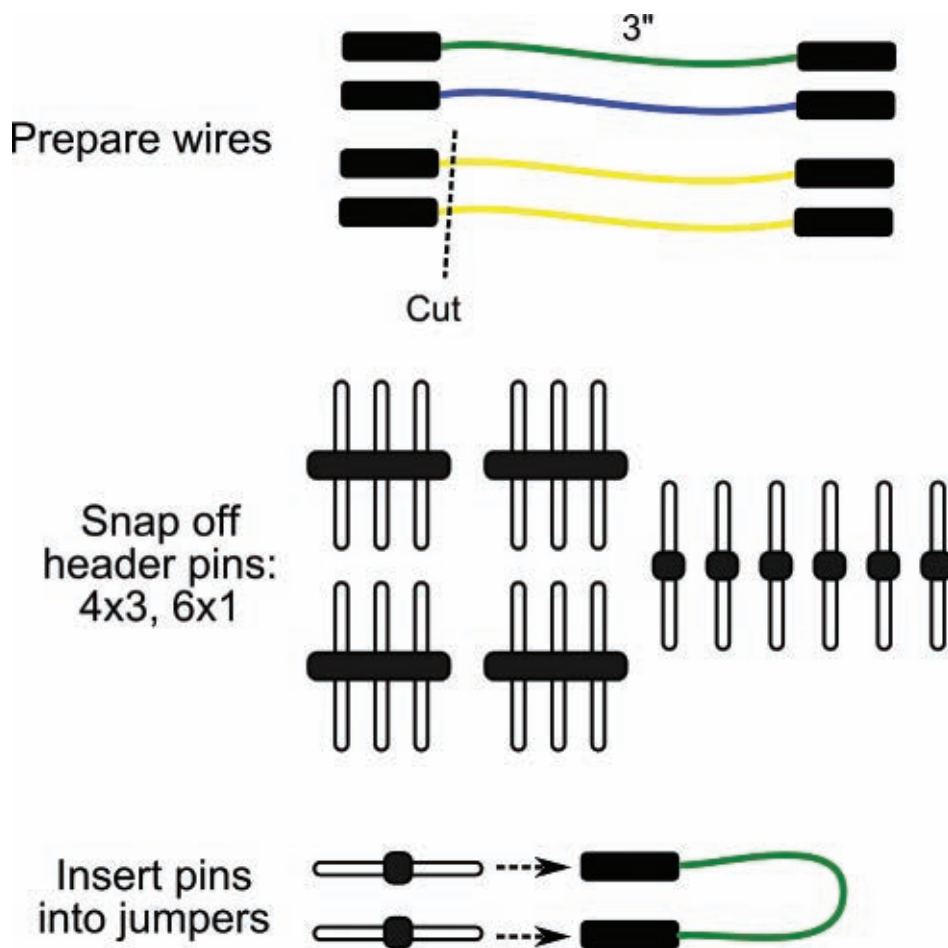


FIGURE 4. For ease of wiring, use pre-made jumpers and breakaway double-long male header pins. These jumpers (available from Pololu) make for neat and tidy wiring on your ArdBot II.

male-male connections. See **Figure 4** for a pictorial list of the pins and wiring.

Take note of the ground connection between the Arduino and the breadboard. Even though the servos run from their own power supply, all the electrical components in your ArdBot II must share a common ground. Otherwise, the robot may operate erratically or not at all. If you forget the ground connection between the Arduino and the servos or the connection comes loose, your bot may stop working. So, this is always a good first place to check if your robot is suddenly refusing your commands.

Installing the Optional Switches

The ArdBot II is equipped with two touch sensors on the front for detecting if it runs into objects. While the switches are optional, I highly recommend you add them so that your ArdBot II has a basic sense of feel. Some of the demonstration programs in upcoming installments of

this series will depend on the switches. As they're fairly inexpensive — about \$2-\$3 each from numerous sources — they're worth taking the time to wire and install.

For the ArdBot II, you want a pair of miniature (not micro) SPDT leaf switches. The bulk of these have a consistent size and shape, and already have two mounting holes on opposite corners of the switch body. See the switches in **Figure 1** for an example. Refer to Part 1 for a more complete list, but online sources for this type of switch include Jameco and All Electronics. SPDT leaf switches will have three connection lugs: Common, Normally Open, and Normally Closed.

You want a switch with an attached metal leaf — the length isn't critical, but it should be at least 3/4". In a bit, I'll show how to add ordinary aquarium or metal tubing over this leaf to extend the "touch zone" of the switch. If you happen to find a pair of leaf switches with longer leaves, that's fine, but avoid anything over about 3".

Solder as shown in **Figure 5**. Start with a 9" length of three-wire servo extension (left over from the battery wiring from Part 1, but shown again for your convenience

Sources

Budget Robotics

Precut ArdBot II body chassis, with all assembly hardware
www.budgetrobotics.com

Selected sources for miniature leaf switches, piezo elements:

All Electronics

www.allelectronics.com

BG Micro

www.bgmicro.com

Jameco

www.jameco.com

Parallax

www.parallax.com

Pololu

www.pololu.com

in the illustration). The red and white wires of the servo extension attach to the Normally Open (N.O.) lugs of the switch; the black wire serves as ground and needs to be jumpered to the Common lug of each switch.

As the lugs on these switches tend to be rather large and mounting space on the front of the ArdBot II is limited, you may find it necessary to bend or break off the remaining Normally Closed (NC) lug if the switch has them. (If your switches have only two lugs each, be sure the lugs are for Common and NO) Switches that only have an NC connection will not work with the demonstration sketches provided in this series.

Physically mount the leaf switches to the front of the ArdBot II using 4-40 x 3/4" machine screws and nuts. If the leaf on the switch is under 3" long, add extensions by cutting to length two pieces of 0.170" inside diameter (ID) clear rubber aquarium tubing. You can get this tubing at hobby fish supply stores and, of course, home improvement outlets. After cutting, just slip over the leaf.

Tip: Cut the tubing a bit long to start, then trim the length as desired.

The switches connect to the Arduino as shown in **Figure 6**. Use a three-pin breakaway male header, and insert between the opposite end of the servo extension and pins 2, 3, and 4 of the Arduino.

Installing the Optional Piezo Speaker

It's always nice to get a little bit of feedback from your robot. Sound is a quick and simple way of doing that. The Arduino lacks sound-making hardware like a speaker, but it's easy enough to add it. Rather than a big 'ol speaker and amplifier that goes to 11, all we need is a mini piezo sound element.

The Arduino can directly drive the element without requiring any additional

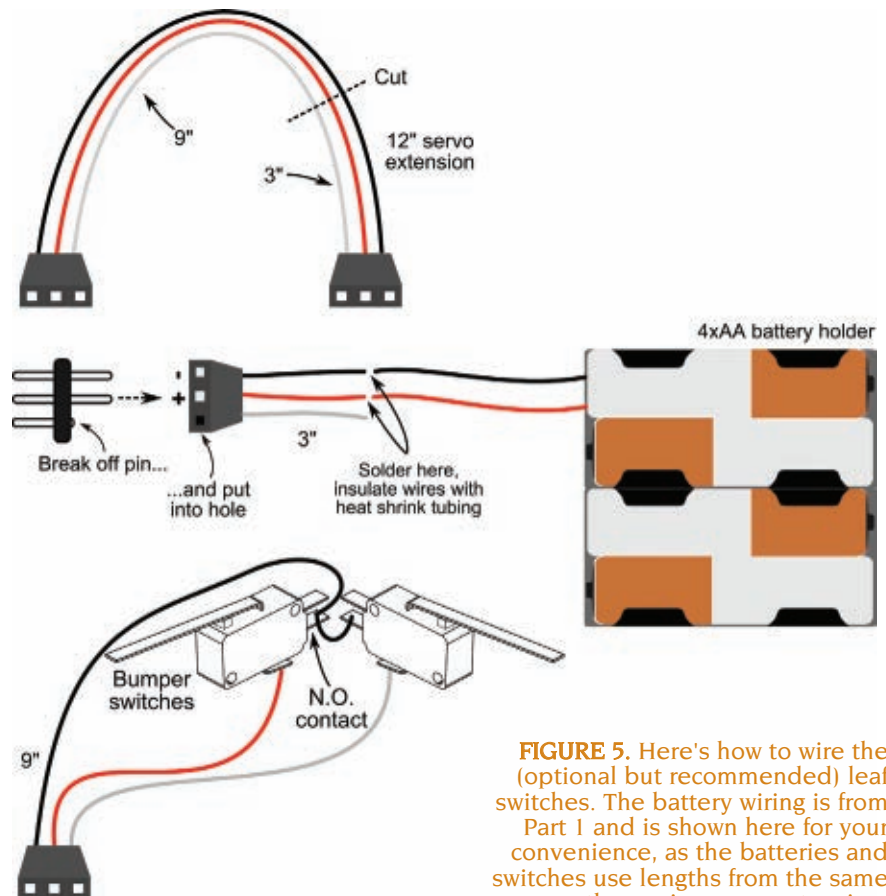


FIGURE 5. Here's how to wire the (optional but recommended) leaf switches. The battery wiring is from Part I and is shown here for your convenience, as the batteries and switches use lengths from the same three-wire servo extension.

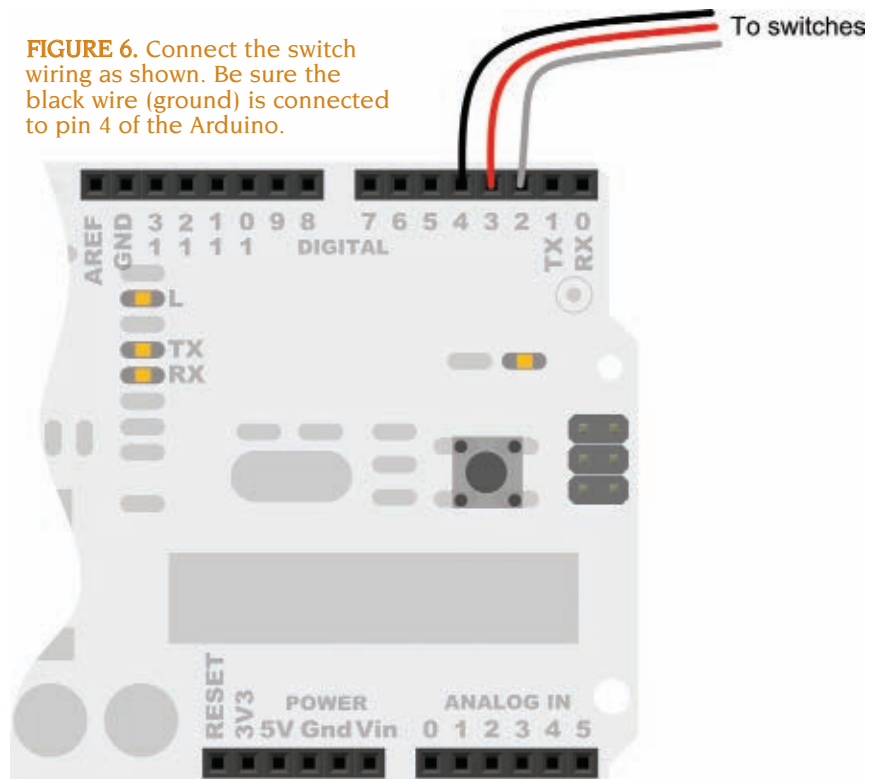


FIGURE 6. Connect the switch wiring as shown. Be sure the black wire (ground) is connected to pin 4 of the Arduino.

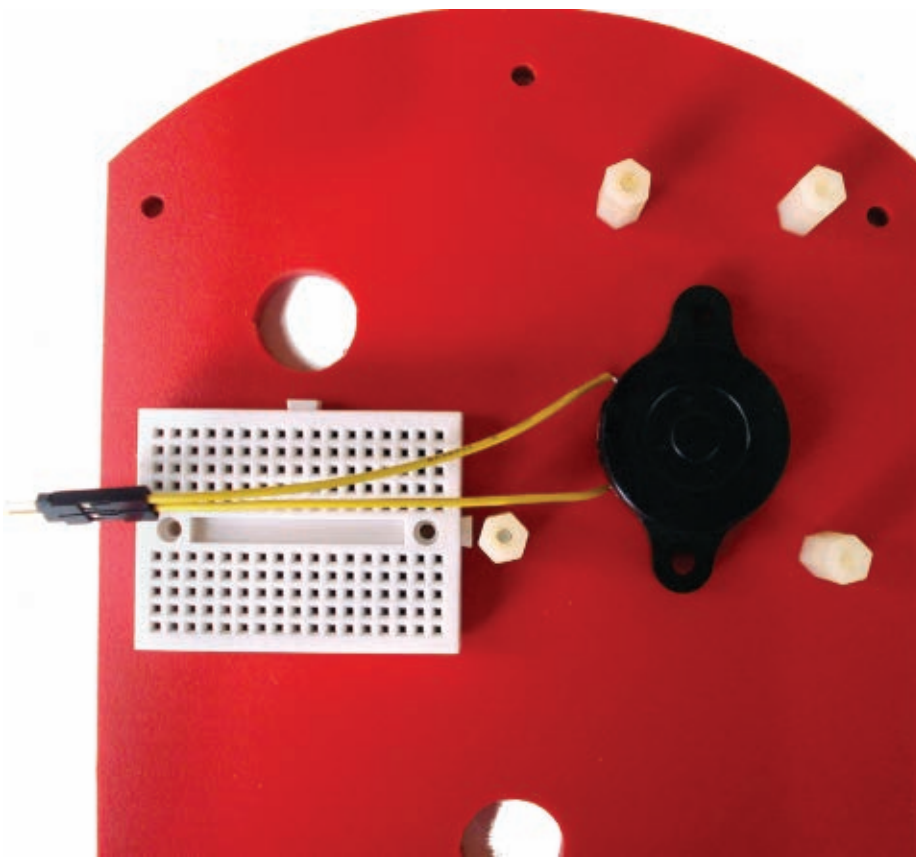


FIGURE 7. Use a "flat pack" piezo element speaker to help your ArdBot II make sound. The element can be mounted in the space underneath the Arduino using double-sided tape.

amplification. The sound level isn't very great — you won't get any complaints from the neighbors because of it — but it's enough to hear over the whir of the ArdBot II's motors.

The choice of piezo speaker is fairly wide open, but I like the larger "flat pack" variety over the small button type. For one thing, the flat pack piezos produce a little more volume, and they're also easier to mount with their flush back that can be attached to the top deck of your ArdBot II using a small piece of double-sided tape.

Alas, it's not always easy to find the kind of flat pack piezo speaker as shown in **Figure 7**. I've had better luck with some of the surplus sources such as All Electronics and BG Micro. As with all surplus, inventory comes and goes, so snatch what you can when it's available. If a flat pack piezo element is simply not handy, then a button type like that available from Parallax will work just fine.

Solder two 3" lengths of jumper wire to the terminals of the piezo element and connect to the Arduino as shown in **Figure 8**. Though most piezo elements have terminals marked + and -, it doesn't matter much how you connect it to the Arduino. (After you get your ArdBot II up and running and depending on how the piezo element was made, you can experiment with flipping the wiring to see if one variation produces a louder sound than the other.)

Important! Make sure you use a standard piezo element, not a piezo buzzer or a dynamic speaker. Here's the difference between them:

- A piezo element consists of just a piezo disc and has two connections (usually marked + and -). These are unpowered and typically produce sound in a range from about 1 kHz to 4 kHz. This is what you want.
- A piezo buzzer is a self-contained sound maker. Apply voltage to its terminals and it makes a constant buzz. It has circuitry in it to produce the tone. These are not useful to us.
- A dynamic speaker uses a magnet and moving voice coil to make sound. While these ordinarily produce better sound than piezo elements, they can consume considerable current — more than the Arduino's output pins can handle. For use on the Arduino, you need one of the following: a dynamic speaker with an input impedance of about 120 ohms or greater; a resistor inline with the speaker to limit current; or a dynamic speaker with an outboard driver transistor or amplifier.

I've called for a piezo element in the parts list as it's just simpler and easier to use. You're welcome to go the dynamic speaker route if you are comfortable with the requirements of interfacing it to the Arduino. Just be sure the speaker does not attempt to draw more than 35 to 40 milliamps of current or you could damage your Arduino.

Tip: If using a flat pack piezo speaker, mount it in the extra space underneath the Arduino board. That leaves more space for other components on the top deck.

Testing Basic Functions: Running the Servos

By this point, your ArdBot II should be complete enough to begin testing. You've built its chassis, added batteries for the electronics and servos, attached your Arduino board and a breadboard, and wired up the

servos, optional switches, and optional piezo element speaker.

With the ArdBot II's mechanical and electrical subsystems complete, you can move ahead and test for basic functionality. **Listing 1** shows an Arduino sketch that "exercises" the two servos. Testing and demonstrating the remaining functionality of the robot is left for the next installment in this series.

To run the sketch, lift the ArdBot II off its wheels so that they don't touch the ground. This prevents your robot from skittering away from you the moment the sketch loads and runs. One or two Isaac Asimov paperback novels make for good testing platforms, and you can always read them between tests!

Verify once more that all your wiring is correct. Be especially cautious of the servo wiring. Ensure that the positive and negative connections to the servos match the battery supply. As noted previously, reversing these will very likely result in two permanently damaged servos.

Connect the battery supplies to their appropriate places:

- 9V cell to the jack on the side of the Arduino
- 4xAA cells to the three-pin header on the breadboard

Connect your Arduino to your computer via a USB cable, copy or open the code in **Listing 1** (it's available for download at the article link), and upload it to your Arduino board.

After uploading, the sketch should start immediately and cause the servo motors to run. Unplug the USB cable from the Arduino, depress the reset button on the Arduino, and set your ArdBot II on the floor in the middle of the room. Release the button. The robot should move back and forth and left and right, demonstrating proper function of

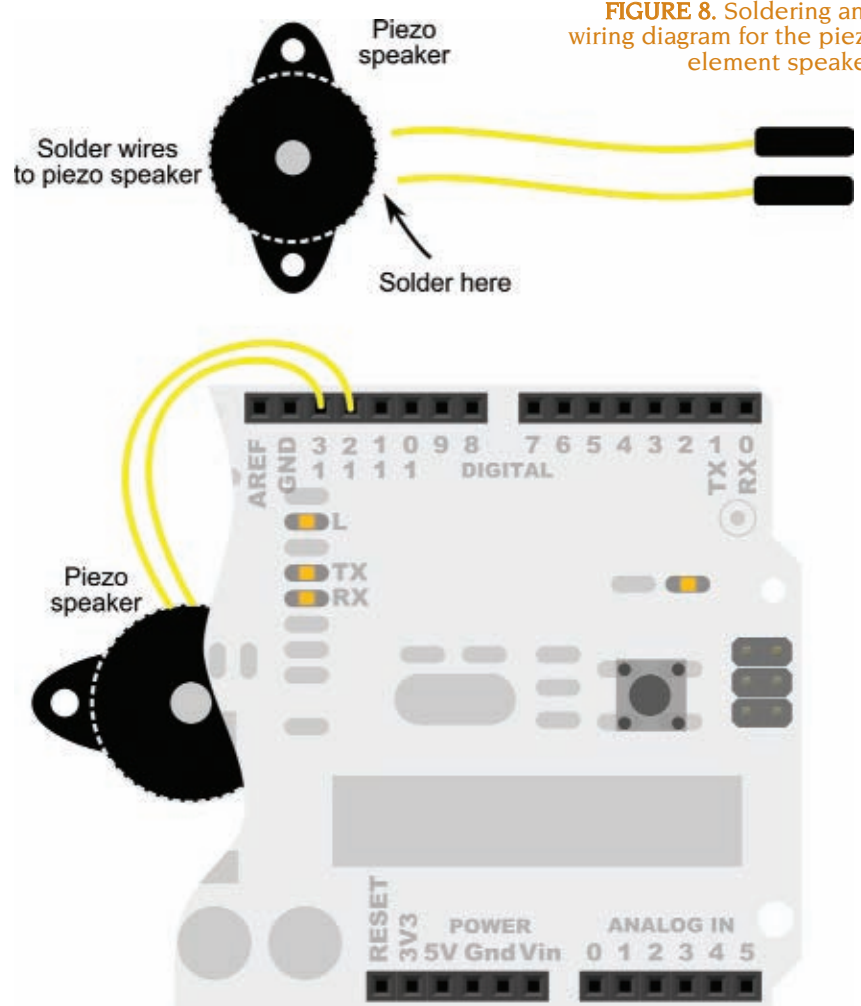


FIGURE 8. Soldering and wiring diagram for the piezo element speaker.

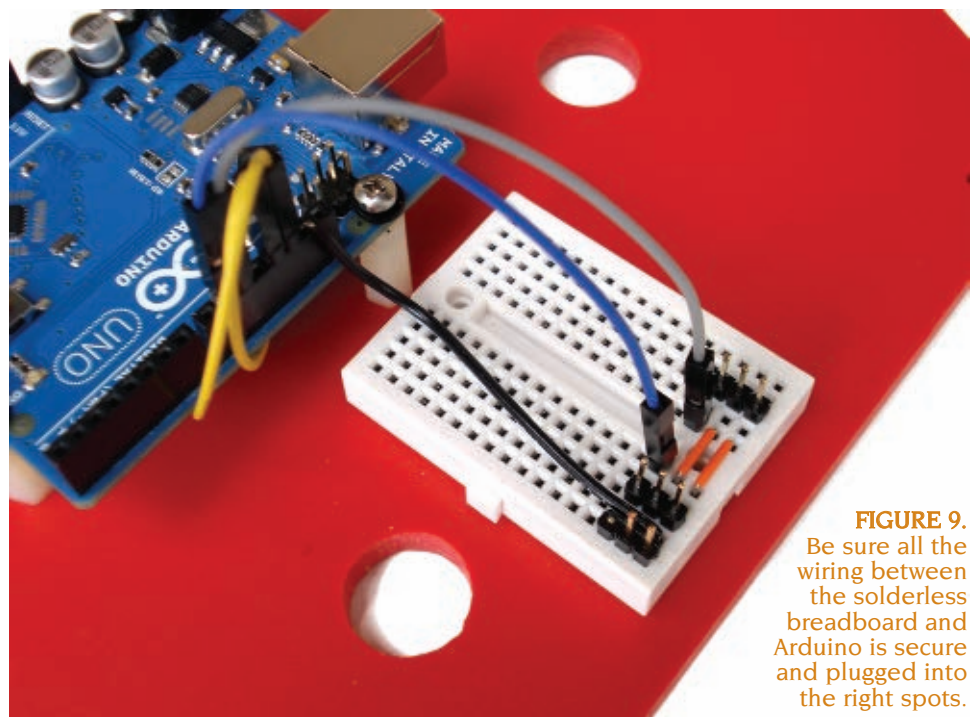


FIGURE 9. Be sure all the wiring between the solderless breadboard and Arduino is secure and plugged into the right spots.

the servos. The cycle of movement will repeat indefinitely until you turn off your ArdBot II by removing its power.

If one or more servos do not operate, troubleshoot the problem by reviewing:

- The power and other wiring for the servos. Is the connector from the AA battery holder firmly in place, and is it in the correct polarity? Check the wiring again on the breadboard.
- The ground connection from the Arduino to the solderless breadboard. If this ground is missing or loose, operation of the servos may be erratic.
- The interconnection from the breadboard to the Arduino. Be sure the two servos are plugged into the correct pins on the Arduino as shown back in **Figure 3**.

If you have trouble seeing the connections on the breadboard, remove the connectors to the AA battery holder and servo. **Figure 9** shows a top view of the ArdBot II, and the relatively simple wiring of the pins and other parts. Except for wire colors, yours should look very much the same.

For the time the piezo speaker and switches are not part of the sketch, they are effectively ignored by the Arduino. Just to ensure their wiring is not having a negative effect, temporarily unplug them and try the demo again.

Once you're done playing with your ArdBot II, disconnect both battery supplies to keep them from draining. Alternatively, you may simply unplug the 9V battery to the Arduino and lift out one of the cells from the 4xAA holder. This way, you run less risk of re-plugging in the servo power using the wrong polarity.

LISTING 1.

```
#include <Servo.h>
Servo servoLeft;           // Define left servo
Servo servoRight;          // Define right servo

void setup() {
    servoLeft.attach(10);    // Set left servo to digital pin 10
    servoRight.attach(9);    // Set right servo to digital pin 9
}

void loop() {
    forward();
    delay(2000);
    reverse();
    delay(2000);
    spinRight();
    delay(2000);
    spinLeft();
    delay(2000);
}

// Motion routines for forward, reverse, turns, and stop
void forward() {
    servoLeft.write(180);
    servoRight.write(0);
}
void reverse() {
    servoLeft.write(0);
    servoRight.write(180);
}
void spinLeft() {
    servoLeft.write(0);
    servoRight.write(0);
}
void spinRight() {
    servoLeft.write(180);
    servoRight.write(180);
}
void stopRobot() {
    servoLeft.write(90);
    servoRight.write(90);
}
```

Coming Up: Turning Your ArdBot into a Touch-and-Go Robot

There's more to test, but we'll leave that for the next installment. Plus, I'll show you how to read the input of the two switches and provide audible feedback through the piezo element, as well as with the Arduino's built-in LED. I'll also demonstrate adding an inexpensive infrared sensor so that you can operate your ArdBot II with a universal remote control.

In future parts of the series, we'll dive even deeper and explore using additional types of sensors such as accelerometers, compasses, and ultrasonic range finders. These other sensors will greatly expand the capabilities of your ArdBot robot, allowing it to see its surroundings and make decisions about where it wants to explore. **SV**

Refer to Part 1 of this series for a full list of mechanical parts for the ArdBot II.



Imagine it. Build it. Control it.™



SERVO ERECTOR SET V1.1



Introducing the Lynxmotion Servo Erector Set (SES) V1.1 with the new FlowBotics Studio V2. The SES V1.1 includes over 500 parts which are used to build and program a variety of different robots including a wheeled rover, biped, quadruped, hexapod and robotic arm. FlowBotics Studio is a powerful, versatile and easy to use graphical software suite which is compatible with a variety of robots and parts. FlowBotics Studio includes the complete FlowStone programming language!

Available now at www.Lynxmotion.com and www.RobotShop.com

Lynxmotion and FlowBotics Studio are trademarks of RobotShop Distribution Inc.



The Road to the DARPA Robotics Challenge

One team's chronicle of what it takes to compete in track "D."

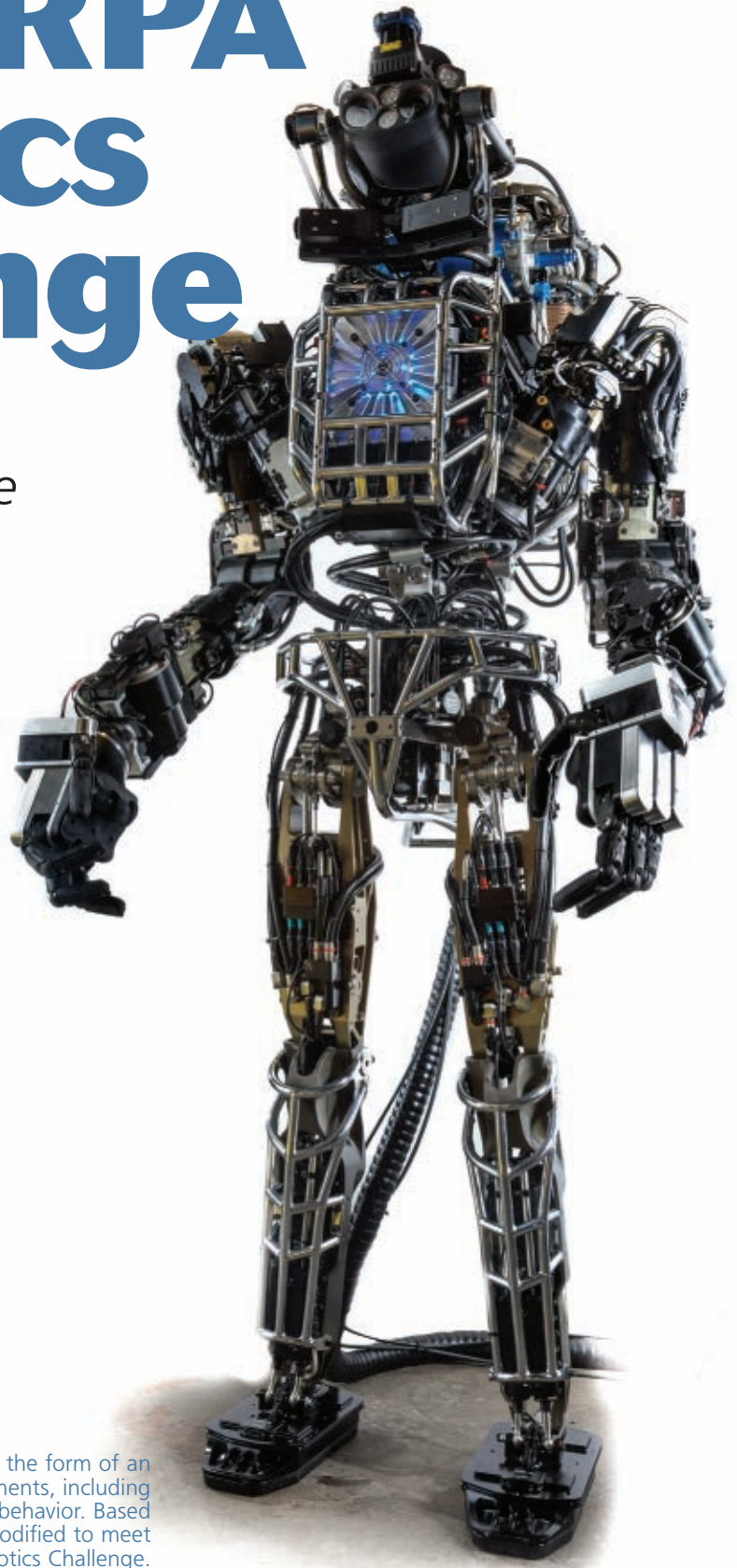
by Daniel Albert and Chris Mayer

In October 2012, the Defense Advanced Research Projects Agency (or DARPA) issued a new challenge. To spur technology advances in robotics, two million dollars in prize money was offered to develop a robot that would be able to operate in rough terrain, use standard hand tools, and even drive a vehicle to a disaster scenario. This is a complex task for software, as well as hardware. To simplify, they decided to divide the competitors into four groups they call tracks.

Track A teams already have their own robots. DARPA will pick up the tab for further hardware development, as well as for a fully funded software development team.

Track B teams are also fully funded by DARPA, but are for squads that do not already have a robot. To allow these teams to focus on the software without needing to worry about building anything, DARPA set up a Virtual Robotics Challenge.

ATLAS (shown here) is a hydraulically powered robot in the form of an adult human. It is capable of a variety of natural movements, including dynamic walking, calisthenics, and user-programmed behavior. Based on the Petman humanoid robot platform, Atlas was modified to meet the needs of the DARPA Robotics Challenge.



Track C teams had to compete to earn a spot in the challenge. Over 100 teams entered to compete with the track B teams in the Virtual Robotics Challenge. The Challenge was held in June of this year. The winners were awarded a state-of-the-art Atlas robot developed by Boston Dynamics. Nine teams were chosen as winners and will continue on the physical challenge.

Track D teams have no funding. They need to compete against the fully funded top research groups on the planet.

Team "Walk Like A Man" is one of the track D teams that have taken the challenge. Our biped WATSON (Without A Tether Stereoscopic Omni-Navigation) was started six years ago. Early versions were covered here in *SERVO* in Dec 2007, and again in a four-part article in the February through May 2011 issues.

This early model could stand but had problems walking. This was due to two major design flaws. First — and very important — is the need to create mechanical stiffness in all joints. Instability in the system prevented the original center of mass algorithm from achieving enough balance necessary to walk. The new rebuild of the platform has reduced the mechanical slop by a factor of five. Mechanical springs have been added to reduce the necessary holding torque in specific positions.

Second is the need for enough torque. The hobby servos available five years ago did not have enough torque and control. Newer servos boast three to six times the torque of our original units. However, in practice, these numbers vary, and the most optimistic torque values tend to be when the DC motor is spinning at its rotational velocity sweet spot.

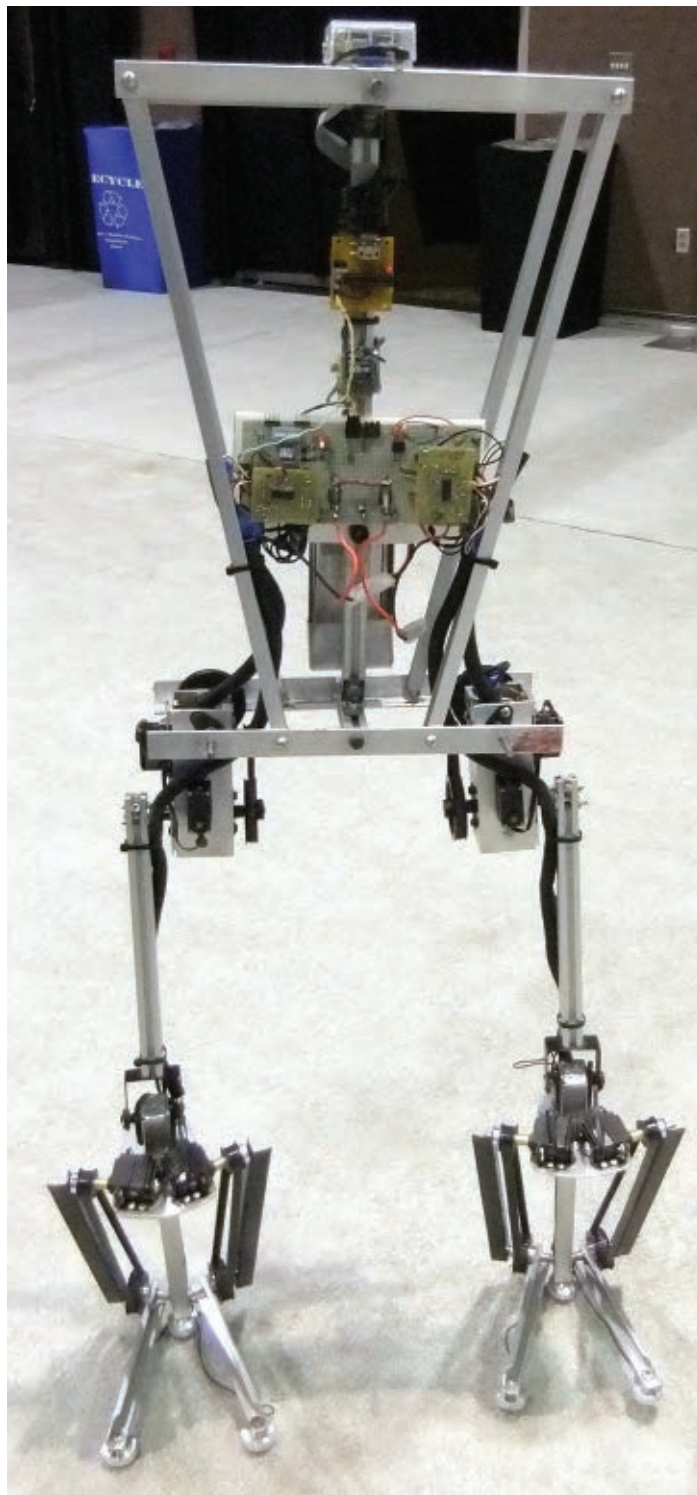
In the first model, only load cells provided feedback for the balancing algorithm. This has been augmented with a nine-axis IMU and a vision system. A neural network is now in development with our smaller test platform. These smaller bipeds have learned to stand and walk on their own. WATSON is bigger, heavier, and prone to more damage when mishaps occur. Our goal is to have the neural net learn rudimentary movements with the smaller bipeds that can be passed on to WATSON.

The Challenges

In December of this year, the DRC Trials will begin. Eight challenges will be given to each team's robot. After each challenge, each team will be able to recharge, repair, or reprogram as necessary. In the final showdown which will be held in December 2014, all eight of these challenges will need to be performed as a single continuous scenario without any breaks. The challenge is meant to mimic a disaster scenario, with the robots coming to the rescue!

1) Driving

The robots will enter a utility vehicle and drive around barrels and barriers to get to the staged disaster scene. This



will include climbing in, releasing the hand brake, putting it in drive, and working the brake and accelerator pedals while steering around obstacles. Once at the site, putting the vehicle back in park and climbing out will complete the task. To eliminate the requirements for fine motor control, the keys will already be in the ignition and turned on. Also, it will be an automatic. No stick shift!



2) Rough Terrain

Once at the disaster site, there will be rough terrain that needs to be crossed; 80 feet of ever increasing difficulties need to be traversed. There will be 10 8' x 8' sections.

It starts out easy with AstroTurf and flat pavers.

Next are angled ramps. It's a flat surface with 15 degree up and down ramps.

The first potential tripping hazards follow; 2x4s and 4x4s will be bolted to the plywood base at random angles. This is followed by slightly higher obstacles: bricks piled up from 6" to 12" high. The next section has the bricks piled up to 32", but not as something to step over. The intention is to walk on top of them, avoiding a potential fall into the 32" deep holes.

These bricks then get piled even higher, so the robots are both climbing up while avoiding the now deeper holes.

After climbing back down, the bricks will no longer be flat. Increasingly tricky placement of the bricks will culminate in a field where every brick is strewn about at an angle, with none of them flat. The final section will be random objects such as rocks and metal up to 12" high. To minimize any potential damage to robots that fall, they will have a safety harness on a zip line.

3) Blocked Door

Now that the robot has made it to the disaster site, the front door will be blocked by debris. Five and 10 pound wooden beams and metal structures will be piled up like a giant game of pick-up sticks.

4) Open Doors

There will be three doors. The first is a simple push-to-open door, followed by a pull-to-open door, and finally a pull door with a weighted spring closure. Instead of doorknobs which might be more difficult to grasp and rotate, they will all be lever handles.

5) Climb Ladder

This will be an industrial metal ladder, tilted at 60 degrees and about 12 feet tall. The steps are 4" deep and 12" apart. This is the only other challenge that will have a safety harness.

6) Break a Wall

There will be a few hand tools such as rotary saws and drills lying nearby. The robots will need to identify the tool it needs, pick it up, and use it to break through a wall. The tools will all weigh 5 kg or less. Rather than actually "breaking through," there will be 4' x 4' panels with only a painted circle that needs to be removed. There will be no studs, just drywall.

7) Close Valves

The robots will need to locate and close a circular or levered valve. They may be horizontal or vertical, and may require one or both hands.

8) Fire Hose

The final task is to locate a fire hose mounted on a wall, unspool it, carry the end 50 feet, and connect it to a fire hydrant.

Can a small unfunded team working in a garage compete against six track A teams (such as NASA), nine track B teams (such as MIT and JPL), and 43 other self-funded teams? We believe the outcome of this "David vs. Goliath" story is not yet cast in stone.

In future articles, we will be talking more about our specific hurdles. We will also address the hardware and software challenges of building a full-sized biped robot. Follow our progress at <http://teamwalklikeaman.com/>.

Go to www.servomagazine.com/index.php?/magazine/article/september2013_Albert for any additional files and/or downloads associated with this article. You can also discuss this topic at <http://forum.servomagazine.com/>.

High-performance networked actuators for robots

DYNAMIXEL

All in One-Actuator

High Power, High Precision

Full Modular Solution

Sophisticated Control Algorithms

Novel Gear Reduction System

Item	Unit	Data		
		H42-20-S300	H54-100-S500	H54-200-S500 (Preliminary Product)
Nominal voltage	V	24	24	24
No load speed	RPM	28.3	35.2	35
No load current	A	0.61	1.06	1.18
Continuous speed	RPM	15.59	32.7	32.1
Continuous torque	Nm	5.596	21.142	39.131
Continuous current	A	1.989	5.930	9.505
Resolution	Step/turn	304,000	502,000	502,000
Gear ratio	-	304	502	502
Backlash	arcmin	3.5	3.5	3.8
Interface	-	RS-485 / CAN	RS-485 / CAN	RS-485 / CAN
Operating temperature	°C	5~55	5~55	5~55



DYNAMIXEL PRO

Internal design structure (Left), / Actual product (Right).



Item	AX-12W	AX-12A	AX-18A	MX-28	RX-24F	RX-28	MX-64	RX-64	MX-106	EX-106+
Gear Ratio (material)	32 : 1 (enpla)	254 : 1 (enpla)	254 : 1 (enpla+metal)	193 : 1 (metal)	193 : 1 (metal)	193 : 1 (metal)	200 : 1 (metal)	200 : 1 (metal)	225 : 1 (metal)	184 : 1 (metal)
Network Interface	TTL	TTL	TTL	TTL / RS-485	RS-485	RS-485	TTL / RS-485	RS-485	TTL / RS-485	RS-485
Position Sensor (Resolution)	Potentiometer (300°/1024)	Potentiometer (300°/1024)	Potentiometer (300°/1024)	Contactless Absolute Encoder (360°/4096)	Potentiometer (300°/1024)	Potentiometer (300°/1024)	Contactless Absolute Encoder (360°/4096)	Potentiometer (300°/1024)	Contactless Absolute Encoder (360°/4096)	Magnetic Encoder (251°/4096)
Motor	Cored Motor	Cored Motor	Coreless Motor	Maxon Motor	Coreless Motor	Maxon Motor	Maxon Motor	Maxon Motor	Maxon Motor	Maxon Motor
Operation Voltage (V)	9.0 11.1 12.0	9.0~12.0	9.0~12.0	11.1 12.0 14.8	9.0~12.0	12.0~18.5	11.1 12.0 14.8	12.0~18.5	11.1 12.0 14.8	12.0~18.5
Stall Torque (N.m)	N/A	1.5 at 12.0V	1.8 at 12.0V	2.3 2.5 3.1	2.6 at 12.0V	2.5 at 14.8V	5.5 6.0 7.3	4.0 at 14.8V	8.0 8.4 10.0	8.0 at 14.8V
Stall Current (A)	1.1 1.3 1.4	1.5	2.2	1.3 1.4 1.7	2.4	1.5	3.9 4.1 5.2	2.1	4.8 5.2 6.3	6.1
No Load Speed (RPM)	360 430 470	59	97	50 55 67	126	67	58 63 78	49	41 45 55	69

USA E-mail : america@robotis.com / Tel : +1-949-333-3635

JAPAN E-mail : japan@robotis.com / Tel : +81-3-4330-3660

Etc. E-mail : contactus2@robotis.com / Tel : +82-70-8671-2609

DYNAMIXEL are registered trademarks of ROBOTIS Co., Ltd.



The *SERVO* Webstore

Attention Subscribers ask about your discount on prices marked with an *

CD-ROM SPECIALS



Free Shipping!

9 CD-ROMs & Hat Special

Only \$ 189.95
or \$24.95 each.

09.2013 FEATURED



Getting Started with
chipKIT™
Uno32
Designed for the
Arduino Community
DIGILENT

Only \$58.95!

Hellebuyck

ROBOTICS

NEW! Arduino Robot Bonanza

by Gordon McComb

Create high-tech walking, talking, and thinking robots. "McComb hasn't missed a beat. It's an absolute winner!"

Breathe life into the robots of your dreams — without advanced electronics or programming skills. *Arduino Robot Bonanza* shows you how to build autonomous robots using ordinary tools and common parts. Learn how to wire things up, program your robot's brain, and add your own unique flair.

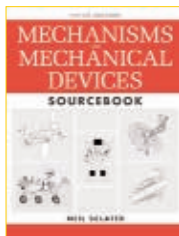
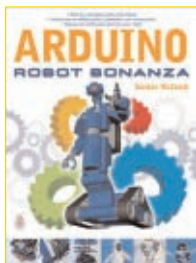
\$29.95*

Mechanisms and Mechanical Devices Sourcebook 5th Edition

by Neil Sclater

Fully revised throughout, this abundantly illustrated reference describes proven mechanisms and mechanical devices. Each illustration represents a design concept that can easily be recycled for use in new or modified mechanical, electromechanical, or mechatronic products. Tutorials on the basics of mechanisms and motion control systems introduce you to those subjects or act as a refresher.

Reg \$89.95



Making Things Move: DIY Mechanisms for Inventors, Hobbyists, and Artists

by Dustyn Roberts

In *Making Things Move: DIY Mechanisms for Inventors, Hobbyists, and Artists*, you'll learn how to successfully build moving mechanisms through non-technical explanations, examples, and do-it-yourself projects — from kinetic art installations to creative toys to energy-harvesting devices. Photographs, illustrations, screenshots, and images of 3D models are included for each project.

\$29.95*



Build Your Own Humanoid Robots

by Karl Williams

GREAT 'DROIDS, INDEED!

This unique guide to sophisticated robotics projects brings humanoid robot construction home to the hobbyist. Written by a well-known figure in the robotics community, *Build Your Own Humanoid Robots* provides step-by-step directions for six exciting projects, each costing less than \$300. Together, they form the essential ingredients for making your own humanoid robot.

\$24.95*



Robot Programmer's Bonanza

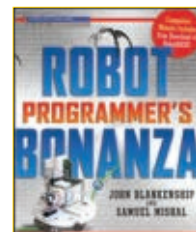
by

John Blankenship,
Samuel Mishal

The first hands-on programming guide for today's robot hobbyist!

Get ready to reach into your programming toolbox and control a robot like never before! *Robot Programmer's Bonanza* is the one-stop guide for everyone from robot novices to advanced hobbyists who are ready to go beyond just building robots and start programming them to perform useful tasks.

\$29.95



Robotics Demystified

by Edwin Wise

YOU DON'T NEED ARTIFICIAL INTELLIGENCE TO LEARN ROBOTICS!

Now anyone with an interest in robotics can gain a deeper understanding — without formal training, unlimited time, or a genius IQ. In *Robotics Demystified*, expert robot builder and author Edwin Wise provides an effective and totally painless way to learn about the technologies used to build robots! **\$19.95**



We accept VISA, MC, AMEX, and DISCOVER
Prices do not include shipping and may be subject to change.

To order call 1-800-783-4624

SERVO Magazine Bundles



**Save \$10.00
Only \$57.95!**

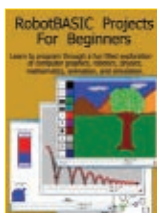
Now you can get one year's worth of all your favorite articles from *SERVO Magazine* in a convenient bundle of print copies. Available for years 04, 05, 06, 07, 08, 09, 10, 11 and 2012.

RobotBASIC Projects For Beginners

by John Blankenship,
Samuel Mishal

If you want to learn how to program, this is the book for you. Most texts on programming offer dry, boring examples that are difficult to follow. In this book, a wide variety of interesting and relevant subjects are explored using a problem-solving methodology that develops logical thinking skills while making learning fun. RobotBASIC is an easy-to-use computer language available for any Windows-based PC and is used throughout the text.

Price \$14.95



Linux Robotics

by D. Jay Newman

If you want your robot to have more brains than microcontrollers can deliver — if you want a truly intelligent, high-capability robot — everything you need is right here. *Linux Robotics* gives you step-by-step directions for "Zeppo," a super-smart, single-board-powered robot that can be built by any hobbyist. You also get complete instructions for incorporating Linux single boards into your own unique robotic designs. No programming experience is required. This book includes access to all the downloadable programs you need.

\$38.95

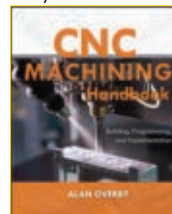


CNC Machining Handbook: Building, Programming, and Implementation

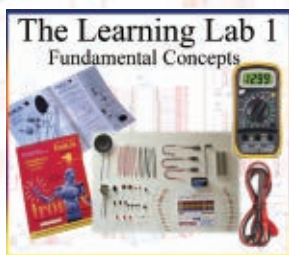
by Alan Overby

The *CNC Machining Handbook* describes the steps involved in building a CNC machine and successfully implementing it in a real world application. Helpful photos and illustrations are featured throughout. Whether you're a student, hobbyist, or business owner looking to move from a manual manufacturing process to the accuracy and repeatability of what CNC has to offer, you'll benefit from the in-depth information in this comprehensive resource.

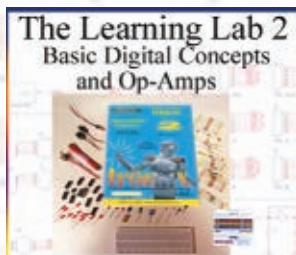
\$34.95



FOR BEGINNER BOT BUILDERS



\$59.95



\$49.95



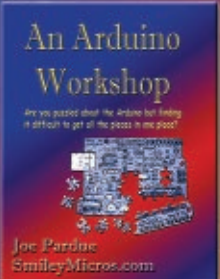
\$39.95

The labs in this series — from GSS Tech Ed — show simple and interesting experiments and lessons, all done on a solderless circuit board. As you do each experiment, you learn how basic components work in a circuit, and continue to build your arsenal of knowledge with each successive experiment.

For more info and a promotional video, please visit our webstore.

Or order online
www.servomagazine.com

SPECIAL OFFERS



Puzzled by the Arduino?

Based on *Nuts & Volts* Smiley's Workshop, this set gives you all the pieces you need!

Book and Kit Combo \$124.95



Forbidden LEGO
 by Ulrik Pilegaard / Mike Dooley

Forbidden LEGO introduces you to the type of free-style building that LEGO's master builders do for fun in the back room. Using LEGO bricks in combination with common household materials (from rubber bands and glue to plastic spoons and ping-pong balls) along with some very unorthodox building techniques, you'll learn to create working models that LEGO would never endorse.

Reg \$24.95 Sale Price \$19.95



Beginner's Guide Complete Combo!



Combo Price \$229.95

VOL 3 Experiment Component Pack

"THE PHANTOM DRAW"

The KILL A WATT meter is the best way to help you determine your actual energy draw in ON and OFF home appliances.

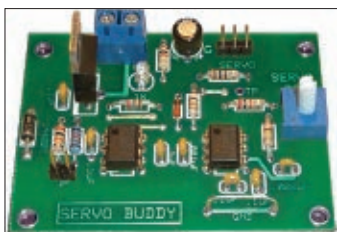
Only \$29.95

To order call 1 800 783-4624 or online www.servomagazine.com



PROJECTS

The SERVO Buddy Kit



An inexpensive circuit you can build to control a servo without a microcontroller.



For more information, please check out the May 2008 issue or go to the SERVO webstore.

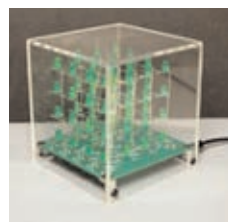
Includes an article reprint.

Subscriber's Price **\$39.55**

Non-Subscriber's Price **\$43.95**

3D LED Cube Kit

From the article "Build the 3D LED Matrix Cube" as seen in the August 2011 issue of *Nuts & Volts Magazine*.

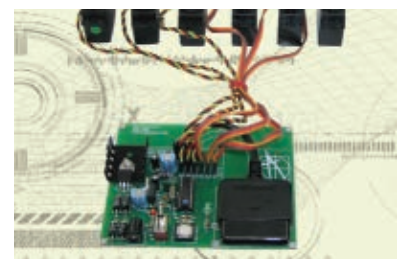


This kit shows you how to build a really cool 3D cube with a 4 x 4 x 4 monochromatic LED matrix which has a total of 64 LEDs. The preprogrammed microcontroller that includes 29 patterns that will automatically play with a runtime of approximately 6-1/2 minutes. Colors available: Green, Red, Yellow & Blue. Jig and plastic cases also available.

Subscriber's Price **\$57.95**

Non-Subscriber's Price **\$59.95**

PS2 Servomotor Controller Kit



This kit accompanied with your own PlayStation controller will allow you to control up to six servomotors.

Includes all components and instruction manual.



For more information, please see the February 2011 edition of SERVO Magazine. Assembled units available!

Subscriber's Price

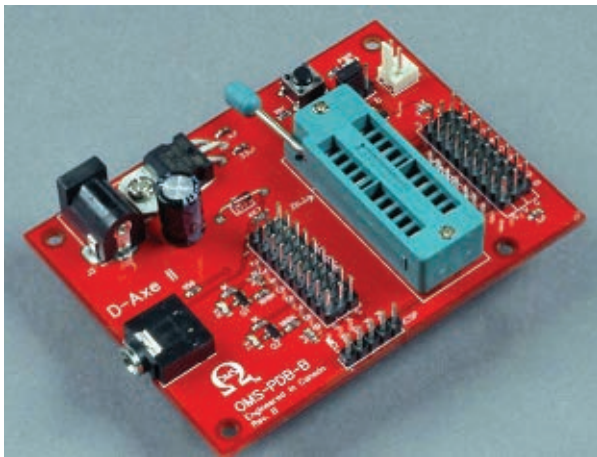
\$79.95

Non-Subscriber's Price

\$84.95

D-Axe II Development Board for the PICAXE

Aztec MCU Prototyping now offers the D-Axe II development board intended primarily for use with PICAXE microcontrollers. Engineered in Canada and carrying their house brand — Omega MCU Systems (OMS) — this board builds on the success of its predecessor and provides a highly versatile and modular platform from which to develop projects based on PICAXE eight-, 14-, and 20-pin microcontrollers. As with all of the OMS branded products, it is designed to speed up the building of prototypes and make the whole process more reliable and repeatable.



The D-Axe II is manufactured using SMD technology on high quality 1.6 mm thick double-sided FR4 fiberglass printed circuit boards with 1 oz copper traces for long life under hard use. All signals from the microcontroller are brought out to three-pin headers that include access to the power and ground. This allows the designer to simply plug in sensor and actuator modules (commonly known as 'bricks') to build prototypes in a matter of minutes.

These same headers allow the D-Axe II to also be connected to solderless breadboards, making it a versatile development platform. It has a 3.5 mm stereo phone jack for compatibility with existing AXE026 and AXE027 PICAXE programming cables, and onboard LEDs indicators to monitor programming and data traffic. An onboard power regulator capable of supplying up to 1A ensures that it can support a large array of modules.

For those situations where a hard reset is required to begin a new program load, the D-Axe II offers a simple pushbutton solution avoiding the traditional means of having to remove the power supply. A zero insertion force socket is used to keep chips in top shape while reducing the handling time. It is fully compatible with all current PICAXE programming software.

While the D-Axe II is primarily intended for use with a PICAXE, it also supports a host of small PIC

microcontrollers via a standard ICSP header.

Benefits offered by the D-Axe II help users get to writing and finishing code as quickly as possible by reducing build time, and increasing reliability and repeatability of the prototyping process. The D-Axe II is available for a limited time for US\$14.99.

For further information, please contact:

Aztec MCU Prototyping

Website: www.aztecmcu.com

If you have a new product that you would like us to run in our *New Products* section, please email a short description (300-500 words) and a photo of your product to:

newproducts@servomagazine.com

FREE Stencil
with every prototype order

Embedded RFID
authenticate, track & protect
your product

www.magic-pcb.com

Call Tyler: 1 707 447 7744
sales@pcb-pool.com

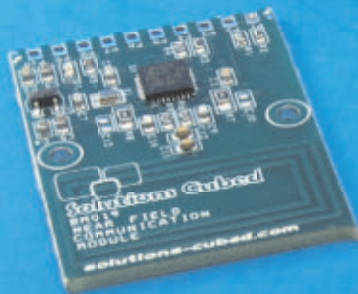
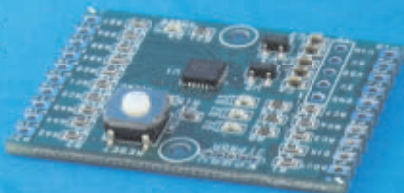
PCB-POOL® is a registered trademark of

www.pcb-pool.com

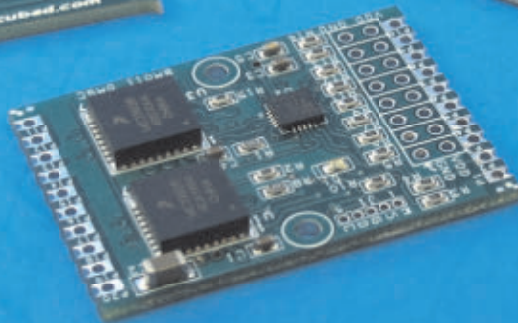
Beta
LAYOUT
create:electronics

Open Source Designs

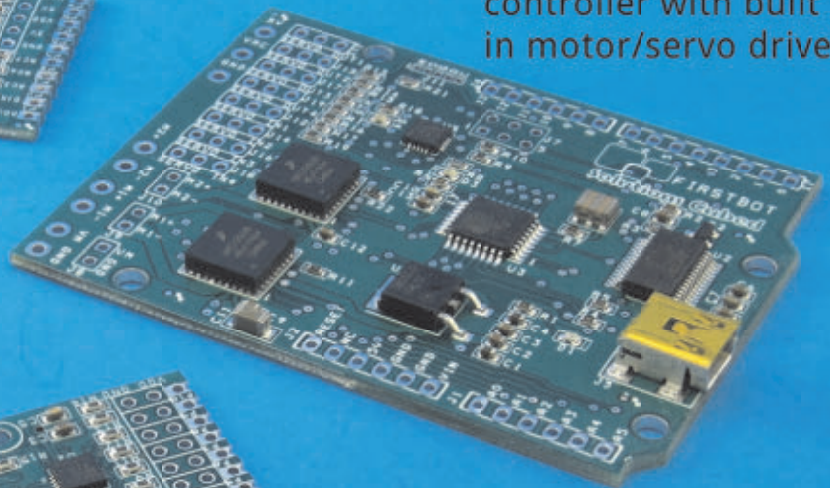
BM013 - \$18
serial control
up to ten
servo output
channels



BM019 - \$16
NFC to serial
interface for
smartcards



FIRSTBOT - \$35
Arduino-compatible
controller with built
in motor/servo drives



BM011 - \$25
dual DC motor control
four servo inputs
four servo output

open hardware, firmware, and software



hardware made easy

Solutions Cubed

designservices@solutions-cubed.com
www.solutions-cubed.com

open source designs
Arduino-compatible tilt
Compass wheel kit
incremental encoder color sensor
load switch servo controls
object detector converters angle
motor controls

by Morgan Berry

Go to www.servomagazine.com/index.php?/magazine/article/september2013_LunaBerry for any additional files and/or downloads associated with this article. You can also discuss this topic at <http://forum.servomagazine.com>.

The Fourth Annual Lunabotics Competition

Back in May, the Visitor's Complex of the Kennedy Space Center — a popular tourist destination — was taken over by a lively group of young college students. Although the opening of the Atlantis exhibit was fast approaching (which houses the retired Space Shuttle Atlantis), the students were not there to relax and enjoy the sights. They came to compete in the fourth annual Lunabotics competition hosted by NASA at the Visitor's Complex. The goal of the competition is to encourage STEM education among college students, while also helping NASA develop an actual lunar rover prototype. The teams design and build a lunar rover that mines a simulated version of the regolith soil found on the moon. These students are some of the best and brightest in their academic field, and NASA is taking full advantage of their talents.

As mentioned, the primary goal of Lunabotics is STEM (Science, Technology, Engineering, and Math) education. The teams learn engineering in a hands-on way by designing and building lunar rover prototypes. At the Lunabotics competition, they put their machines to the test in a pit of simulated regolith, competing with other teams to mine the moist soil. In addition to the amount of regolith the Lunabots mine, teams earn points for making a lighter and more compact bot, dust-proofing their machine, having a multidisciplinary team, and other criteria.

These categories were designed to encourage teams to develop creative solutions to problems that a lunar rover would likely face in a real world

application on the moon. Every unique idea that the teams develop brings NASA one step closer to fine-tuning their actual lunar rover.

Students learn other skills for their future STEM careers in the competition, as well. The teams are required to write a systems engineering paper. This is basically a roadmap of how the students will design and build their bot. It is a frequent task of engineers in the real world. By learning this skill at Lunabotics, participants will have a leg up as they enter into their chosen field.

An outreach project where teams are required to give presentations or demonstrations about Lunabotics in their local community teaches the students how to educate others about their work.

A slide presentation judged by NASA engineers is good practice for similar presentations that the students may do while working in their future careers.

This year at Lunabotics was exciting, as teams are branching out further and further to create innovative Lunabots. One notable change this year was that the number of teams experimenting with autonomous control systems seemed to have increased over previous years. This is an important step in the design process for a real lunar rover, as NASA's rovers typically use an autonomous control system. Check out the following collection of photos to get a feel for what it was like at this year's Lunabotics competition.

Photographs courtesy of Joe Jacoby.



The LunArena is the heart of the competition. Live feeds that show the mining attempts in the pits keep teams filled in on what is going on with their competition. The teams who aren't hard at work in the pits or visitors to the complex who are interested in the event, can watch each attempt through the Plexiglas walls of the LunArena. Outside of this area, teams waiting for their turn to compete stand anxiously underneath a tent with the robots they have worked on for months to perfect.



Students in the competition tend to be an upbeat and lively bunch, not letting the sweltering heat dampen their school spirit. This team from the University of Akron enchanted our photographer into snapping a picture of them spelling out "S.T.A.C.E.E." — the nickname given to their Lunabot. S.T.A.C.E.E. stands for Systematic, Technical Automation Collecting Extraterrestrial Elements. This free-spirited attitude not only makes the competition more fun, but could also benefit the group by aiding them in the Team Spirit award category.



The Kennedy Space Center Visitor Complex is the perfect venue for this unique competition. Set against the backdrop of the Rocket Garden which displays retired rockets that are a fitting tribute to NASA's past victories, this event aims to shape the future of space exploration. Since NASA scientists won't have the luxury of being in the same room — or even the same planet — as a lunar rover, the same rules apply to the Lunabotics students. They must operate their bot from a command center bus, where they view the LunArena and their Lunabot on small closed-circuit television screens. The bots must operate wirelessly. Additionally, teams have the opportunity to score added points if they are willing to experiment with the riskier autonomous design.



The team from nearby Embry-Riddle Aeronautical University in Daytona Beach, FL prepared for this event using a mixture of sand and construction dust. This small team had worked very hard to develop an autonomous system for their robot. To practice the autonomous controls, the team used a full-sized cardboard model of the LunArena — complete with obstacles — in order to prepare for their mining trip.

The team from nearby Embry-Riddle Aeronautical University in Daytona Beach, FL prepared for this event using a mixture of sand and construction dust. This small team had worked very hard to develop an autonomous

2013 Lunabotics Competition Results

Joe Kosmo Award for Excellence (Grand Prize)

First Place - Iowa State University in collaboration with Nebraska Indian Community College & Wartburg College
Second Place - West Virginia University in collaboration with Bluefield State College
Third Place - The University of Alabama in collaboration with Shelton State Community College

On-Site Mining Award

First Place - Iowa State University in collaboration with Nebraska Indian Community College & Wartburg College
Second Place - University of North Dakota
Third Place - University of New Hampshire

Judges Innovation Award
 Montana State University

Efficient Use of Communications Power Award

First Place - University of New Hampshire
Second Place - Montana State University
Third Place - Universidad de Los Andes in collaboration with Virginia State University

Systems Engineering Paper Award

First Place - The University of Alabama in collaboration with Shelton State Community College
Second Place - Military Institute of Science and Technology
Third Place - John Brown University

Outreach Project Report Award

First Place - Military Institute of Science and Technology
Second Place - Kirori Mal College-Cluster Innovation Centre, University of Delhi
Third Place - Iowa State University in collaboration with Nebraska Indian Community College & Wartburg College

Team Spirit Award

First Place - Florida Institute of Technology

Second Place - West Virginia University in collaboration with Bluefield State College
Third Place - Military Institute of Science and Technology

Slide Presentation and Demonstration Award

First Place - The University of Alabama in collaboration with Shelton State Community College
Second Place - John Brown University
Third Place - University of Akron

Luna Worldwide Campaign Award

First Place - Military Institute of Science and Technology
Second Place - Kirori Mal College-Cluster Innovation Centre, University of Delhi
Third Place - Bangladesh University of Engineering and Technology

Social Media Award

Universidad de Los Andes in collaboration with Virginia State University

Perseverance Award

Warsaw University of Technology



When we interviewed the team from the University of North Dakota, they were enjoying a brief moment of calm after their first trip into the LunArena. Using a rotating drum design, the team mined 94 kg during the first round — one of the most impressive totals of the day. Even with this early success, the team was not planning to take the rest of the competition for granted. Team member Benjamin Storhaug expressed a desire to improve the team's overall timing during their mining trip, ultimately wanting to mine 100 kg.



One potential problem the University of North Dakota needed to focus on was the fact that the closed collection drum design makes it impossible to know how much regolith is inside the drum. Potentially, the robot could become top-heavy and the robot's performance could suffer. Team member Storhaug said that careful practice and coordination was the team's method of dealing with this potential issue. The team also needed to repair some general wear and tear before the next round of competition. Overall, the University of North Dakota had an excellent year at Lunabotics, placing second in the mining portion of the competition.



The team from India's Kirori Mal College traveled about 17 hours for the competition. Wanting to show some patriotism for their country, the team decided to decorate their Lunabot with the Indian flag. This team was awarded second place for the Luna Worldwide Campaign award. This new aspect of the competition was designed to popularize the event's mascot Luna. The teams were challenged to bring a printout of Luna to their community outreach events — a requirement for the competition. Then, the teams took pictures of the mascot's "adventures" and uploaded them to Facebook and Twitter. This new award demonstrates NASA's emphasis on social media which is important if the organization wants to remain relevant in the digital age.

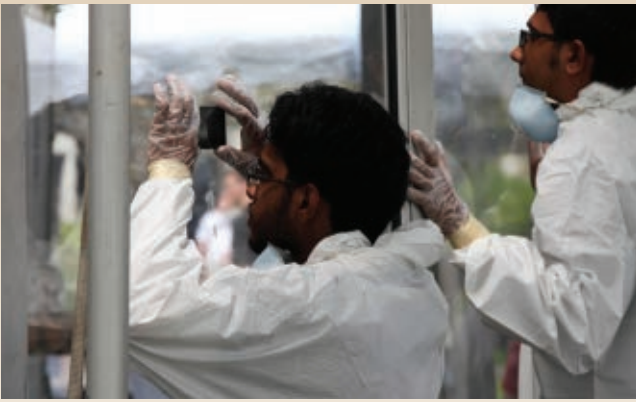


Inside the pit, the team from the University of Sydney took time away from last-minute repairs and tweaking on their Lunabot to talk to *SERVO*. Clearly one of the more well-funded teams, the University of Sydney wore matching shirts and brought a custom display for their pit — complete with a bar code that smartphones could scan to reach more information about the team online. This team used a bucket ladder design for their robot. Their design can scoop up to 30 kg of regolith at a time.

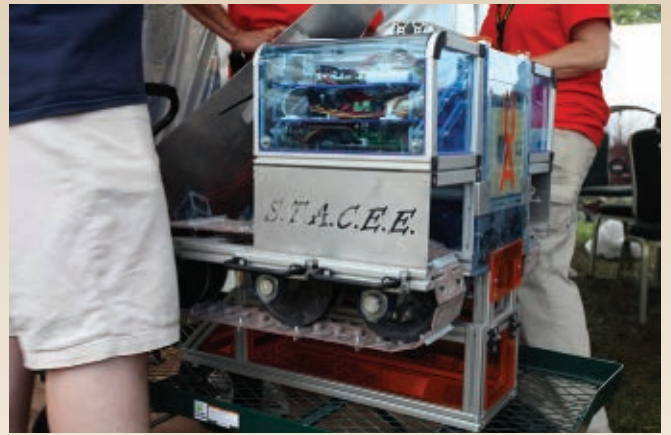
After the team's first attempt in the LunArena, Sydney appeared to be optimistic about the competition. Although the team had experienced some connectivity issues that resulted in some lagging during the attempt, the team did manage to mine 18 kg of regolith. This was enough to qualify them for the next stage of the competition.

Keep in mind that the international teams at Lunabotics face an added challenge that most North American teams do not contend with. These teams have to disassemble, ship, and reassemble the robot they have invested so much time and money into building. During the 19 hour flight across the globe to Central Florida, all the team could do was wait and hope everything with the shipping process would go smoothly. One hard bump could destroy the team's hard work. Fortunately though, fate was on the University of Sydney's side, as the shipping went off without a hitch.





While the team members who operate the Lunabot do their best to navigate the LunArena, other members have no choice but to sit back and watch. The teams are required to mine a minimum of 10 kg of regolith and pass through some lunar obstacles during their turn in the regolith pit. These students are part of the team that transports the robot into and out of the arena. Although wearing the thick white suits in the middle of Central Florida's 90° heat was uncomfortable to say the least, they are a necessary safety requirement. The simulated regolith could easily get into the student's eyes and throats when they bring their robots into the LunArena.



Proudly displaying the University of Akron logo, S.T.A.C.E.E. was the culmination of more than a year of work by the team. Team Captain Ben Chaffee says that their design was all about simplicity, with the bucket and two treads being the only moving parts on the robot. The team reasoned that with fewer moving parts, fewer things could go wrong during their time in the LunArena. Although S.T.A.C.E.E. didn't bring home a medal for mining this year, the University of Akron did not go home empty-handed. The team placed third for the Slide Presentation and Demonstration award which requires the teams to present their robot to an audience of NASA and private-industry judges. This category is important because it teaches the teams how to present their work — a crucial skill for anyone who wants to be successful in a STEM career.



This was probably the most common sight as we made our way through the rows of tables in the pit. This competition is very important to the students involved (many are participating as a part of design projects for course credit) and it is easy to see the hard work and dedication that they all possess. In addition to the chatter between teammates

and the buzzing of electrical tools, a frequent sound heard in the pits were the gasps and cheers of members from other teams as they watched their competitors mine regolith. It appeared that the students enjoyed experiencing Lunabotics as a spectator sport as much as participating in the actual event. Lunabotics is all about balancing work and play — something students tend to know all too well as they navigate the college experience.



A major sponsor of the event once again this year was heavy machinery producer Caterpillar Inc. This seems fitting because Caterpillar products are basically designed with the same goals in mind as the Lunabots: to collect a large amount of soil. In fact, many of the Lunabotics

teams modeled their bots after this type of machine, citing the effectiveness of Caterpillar machines in the real world at construction sites as evidence that the "scoop" design is effective.

"Caterpillar has a long history of supporting educational opportunities that promote the STEM areas. We need to encourage technology, innovation, and ingenuity to students of all ages. The development of autonomous systems will ultimately help our global customers boost safety, efficiency, and increase profitability," said Eric Reiners, a manager at Caterpillar.

Embry-Riddle's Lunabot had some of the most interesting design elements that we saw this year. For one thing, the collection system and the base of the robot are completely separate and operate independently of each other. Team member Jodi Lynn Clark explained that the team hoped to be able to reuse the base in years to come, and simply attach a new and improved collection system. Another creative aspect of Embry-Riddle's Lunabot was the wheel design. The team designed flexible wheels that sag under the weight of the robot. As the robot moves, the wheels conform to the shape of the ground, allowing the holes to sink into the soil and provide crucial traction.

LEGO Mindstorm Robots at the 2013 Lunabotics Event

by Morgan Berry

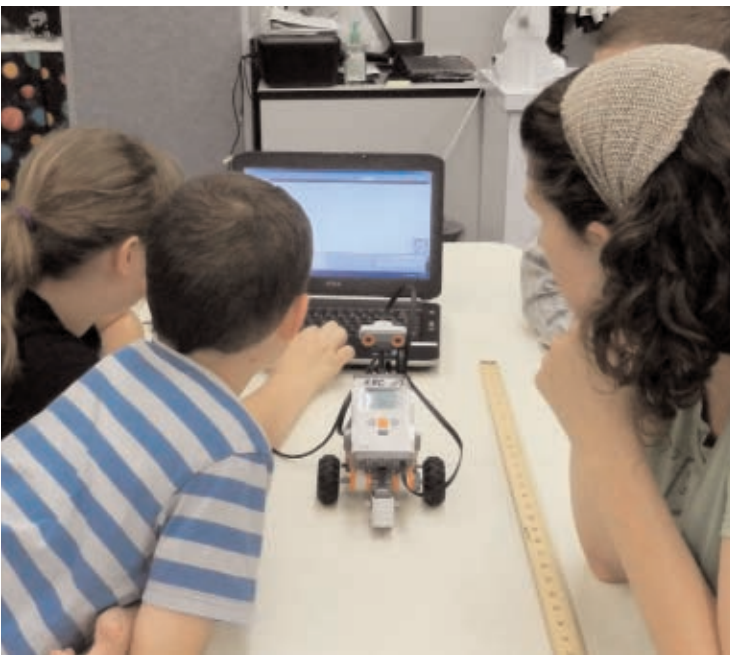
Go to www.servomagazine.com/index.php?/magazine/article/september2013_LEGOBerry for any additional files and/or downloads associated with this article. You can also discuss this topic at <http://forum.servomagazine.com>.

During the week-long Lunabotics tournament, NASA held robotics workshops free of charge to school-aged children based on the LEGO Mindstorm set. The event was a part of NASA's larger community outreach program to foster a love of science, math, technology, and engineering in children. The session *SERVO* sat in on was a special workshop for the children of Kennedy Space Center employees, but summer camps and daycares had also participated in sessions during the week. The youngest children in attendance were preschool aged, while the oldest few appeared to be in middle school. Regardless of age, everyone had a great time playing and — more importantly — learning using the LEGO Mindstorm robots.

The first step for the children was (naturally) to pick a name for their bot. Some of the older children decided that "Wookiee" was a fitting name for their Mindstorm creation, while the youngest one was insistent that her table's robot be named "Whiskers" — much to the amusement of all the adults in the room. The software that accompanies LEGO Mindstorms — NXT 2.1 — is very child-friendly, utilizing a simple



The LEGO Mindstorm is the programmable robotics kit featured in NASA's workshops. It's easy for kids to understand, but has enormous potential to teach them about robotics.



Jennifer, Ethan, and Alyson were some of the attendees of the workshop. The enthusiastic kids loved learning how to program their robot, and even asked their mom if they could take home the kit with them.



Soon after the hands-on portion of the class began, kids began to head up to the premade paths to experiment with different timings for their robots. After a few failures, they began to realize they could apply the measurements they had taken earlier to the paths, and soon were successfully programming the Mindstorms to follow the tape.

drag-and-drop system that even the youngest participant could easily navigate with a little guidance. The teachers let the kids program facial expressions and sounds into their robot, allowing them to express their creativity. Some of the favorites were the smiley face, the surprised face, and the laughing noise. Next, the students connected their robot to the computer with a USB to download their choices onto the LEGO Mindstorm.

Next came the more challenging portion of the class. Ultimately, the children would learn to program their robot to navigate a simple maze that was taped out on the floor. Before that, the goal was simply to program the robot to travel one meter by guessing the number of seconds it would take for Mindstorms to go the correct distance. After that task was mastered, the children had to determine how long it would take for the robot to travel the meter, turn around, and come back. With this came the added difficulty of guessing how much time the Mindstorm would spend making the 180° turn.

All together, this was a pretty complicated job for the younger kids, but everyone was surprisingly focused on the task at hand. As the teachers let the kids experiment by themselves with the robots, children loudly exclaimed things like "Guys, we did it! It's almost there!" and "Look Mom, it came back!" It was easy to see how much the children were enjoying themselves.

The leaders of the workshop — Lynn Dotson and Jennifer Hudgens — explained how they approached the task of teaching children about robotics. The most important thing was an enthusiastic attitude. They don't want to overwhelm the children — especially the younger ones, they said. As a result, they break the task into very manageable steps which add up to more complicated ones. Before long, kids were making their way up to the taped out path, using meter sticks to measure the length the robot would need to travel, and running back to their computers to program the calculations into their Mindstorm.

Dotson and Hudgens firmly believe that reaching children early is the key to creating enthusiasm about science and technology. So far, the two are doing their job; more than 300 kids had attended the workshop this year, with a few more sessions planned for that particular day. NASA also gave out eight Mindstorm sets to the schools that had visited the workshop to solidify the interest they had sparked.

The parents were pleased with the results of the workshop. Jessica, a KSC employee, brought her two children (Ethan and Alyson) to participate in the event. Ethan and Alyson were so enthralled with the robot they could hardly be pulled away for an interview, simply saying that the Mindstorm was "fun, and they really needed to buy one for home," before turning back to their programming tasks. Their mother explained that she thought it was very important for kids to be involved in these types of programs because they make robotics fun and attainable. As someone



Jennifer Hudson (one of the workshop leaders) went around the room helping some of the families, while Lynn Dotson gave instructions from the front of the room.



The teachers projected the software onto an interactive white board while teaching the children how to use it. It is very easy software to navigate, allowing most of the parents to step back while the kids learned to program the robots on their own.



Children broke out into huge smiles as the hard work they had put into programming the robots began to pay off. It was very inspiring to see the genuine interest the kids were taking in robotics during the workshop. Perhaps some of the kids who attended these sessions will grow up to become some of the best and brightest engineers one day.

who works in the technology field herself, Jessica knows all too well that not many children are exposed to robotics at an early enough age — something she wanted to make sure her children would get to experience.

Through programs like the LEGO Mindstorm programming workshop, NASA is trying to create the next generation of robotics enthusiasts, potentially becoming a "launching pad" to the engineering field for the young minds who attend the events.

SV

The workshop for Kennedy Space Center employee families was very popular. The instructors had a full crowd for this event — one of many that took place for the families that day.



You can discuss this topic at
<http://forum.servomagazine.com>.

Parallax, Inc.

Virtually everyone who has been into robotics for a while — at least in the United States — knows about Parallax. Most of these people know about their BASIC Stamp microcontroller and the newer multicore Propeller microcontroller with eight cogs (processing cores). Quite a few of these people have also built and experimented with the Parallax Boe-Bot robot. This beginner's robot is used by self-learners and in schools around the world. The open platform exposes circuitry for easy building. Available step-by-step projects cover wiring and source code tuning, and sensors (touch, light, and infrared) allow the Boe-Bot to navigate on its own. The expandable robot can be upgraded with additional sensors and expansion kits, such as a panning sonic range finder; Bluetooth and Wi-Fi RF communications; IR sensors; and even speech and speech recognition. Check it out in Figure 1.

Parallax, Inc., is a privately held company located in Rocklin, CA. I have had the pleasure of visiting their offices on three occasions. I am amazed at the wide variety of products this company produces, and I feel that readers of this column might like to know a bit about their history and background.

Parallax designs and manufactures microcontroller development tools, small single-board computers, and many other products applicable to robotics, electronics, technical, educational, and industrial applications. Their current product line consists of BASIC Stamp microcontrollers and development

software, Propeller chips and tools, project boards, robotics kits, educational tools, and sensors, among many others.

A full 42% of Parallax customers are educators; 32% are interested in industrial or commercial applications; and 26% are experimenters and hobbyists. Parallax's core business is in microcontroller education and commercial applications with their Propeller multicore microcontroller.

One of the first things that I have observed about Parallax is their great customer service. A call or email to the company will result in a reply to the customer with an answer to their question or comment. If the staff

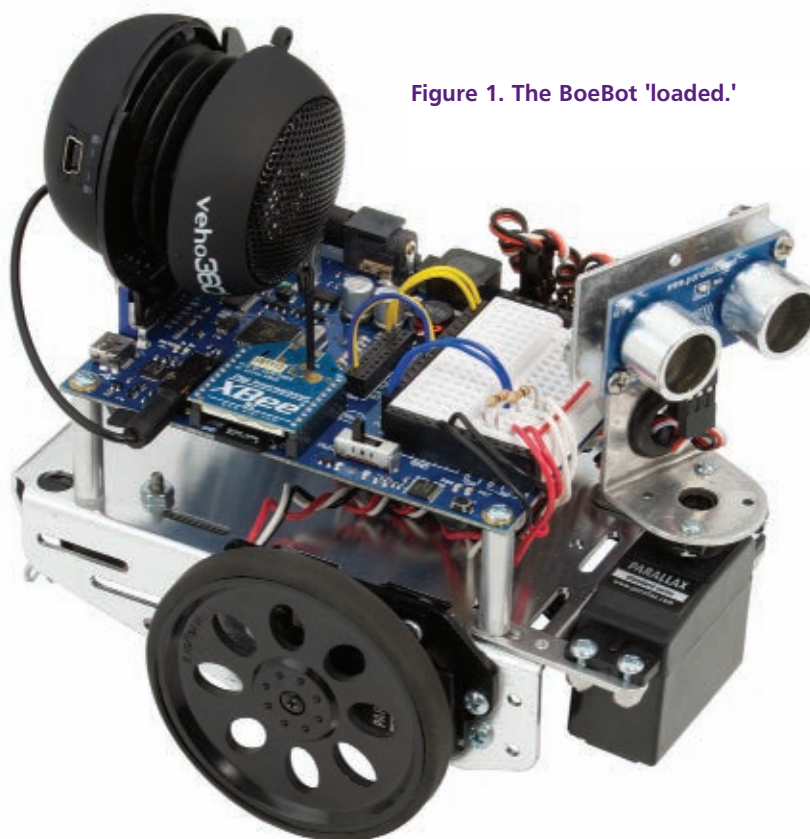


Figure 1. The BoeBot 'loaded.'

does not have the best answer at the time and the query is not resolved, a company representative will refer the customer to another company or product.

Speaking of products, another great attribute of the company is how they strive to produce as many of their products here in the US. Their in-house production facilities are excellent for a small business as I had the chance to tour the complete plant. I'll discuss the different production tools a bit later.

Beginnings

Chip Gracey first envisioned what is now Parallax just after graduation from high school in 1986. Prior to that time and typical of most tech startups, Chip was a typical computer nerd with extensive knowledge of the Timex Sinclair, Apple II, and Commodore 64 computers from his middle school and high school days. He was actually asked by his middle school teacher to instruct other students in computer technology.

Writing Basic programs for the different machines, he managed to turn everyday household appliances into things other than their intended use. By the time he was a high school senior, Chip was running a small business called Innovative Software Engineering from his bedroom that made software duplication hardware for the Commodore computer. He graduated from high school in 1986 and tried a few community college courses, but left uninspired by the level of the educational system. His own technology experience was the driving force to his success.

Chip and a friend, Lance Walley started Parallax from their apartment. Lance brought practical skills in writing, graphics, and programming to the team to complement Chip's technical prowess. Lance was responsible for developing the company's infrastructure and making Chip's creations marketable. The two had a board of directors that consisted of an accountant, attorney, and engineer, along with the two of them.

This board provided positive direction for Chip and Lance assisting them with business problems, but also arranging the different legal operating aspects of a new business.

Their early products were Apple computer sound accessories. In 1990, Parallax released a third-party PIC programmer version that was sold to Microchip, but the later versions made by Parallax sold over 12,000 units during the next six years.

Ken Gracey (Chip's brother) is now the president of the company as Chip spends most of his time in the very detailed development process of the new Propeller 2 and other company projects as director of R&D. It has been Ken who has introduced me to their new products over the past few years, along with Lauren Davis, Marketing & Sales Director.



Figures 2 and 3. BASIC Stamps.

The BASIC Stamp Microcontroller

It was his experience with Microchip's PIC programming that led Chip to the development of the first postage stamp-sized BASIC Stamp microcontroller module. The Stamp (see **Figure 2** and **Figure 3**) was the first of the series that came out back in 1992. It became so popular in the beginning that the company had to extend from three to five employees. As their bio reads: "The fact that the BASIC Stamp modules would create its own industry was probably unknown by Parallax founders, but it quickly became apparent that the small computer had its own group of enthusiasts."

Six years after its introduction, Parallax had sold over 125,000 Stamp modules, and distributed a complete series of supporting peripherals through over 40 world-wide sales channels. By April of this year, there were over five million Stamps in use.

The tiny microcontroller module allowed ordinary people to program for the first time. The powerful I/O commands made it easy to connect to other electronic components. The user base is tremendously diverse. There's everything from hobbyists to entrepreneurs, scientists, and engineers."

Parallax created the "Stamps In Class" program in 1997 to address the needs of high school students. Their comprehensive program is designed to introduce students and educators to the Stamp microcontrollers using software basics and simple hardware, such as the latest Propeller-based Boe-Bot robot platform. The Boe-Bot — mentioned earlier — is their best-selling robot kit which is a programmable and expandable wheeled robot that is used by educators and hobbyists.

Not everyone who desires to learn about microcontrollers will end up building a robot, but this platform allows a person to learn about implementing motor control, sensors, RF links, sound processing, and

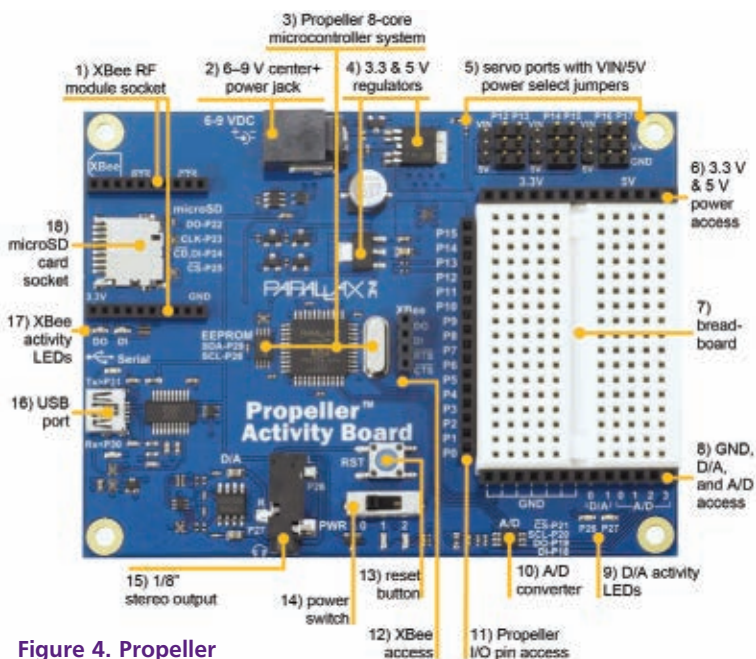


Figure 4. Propeller Activity board.

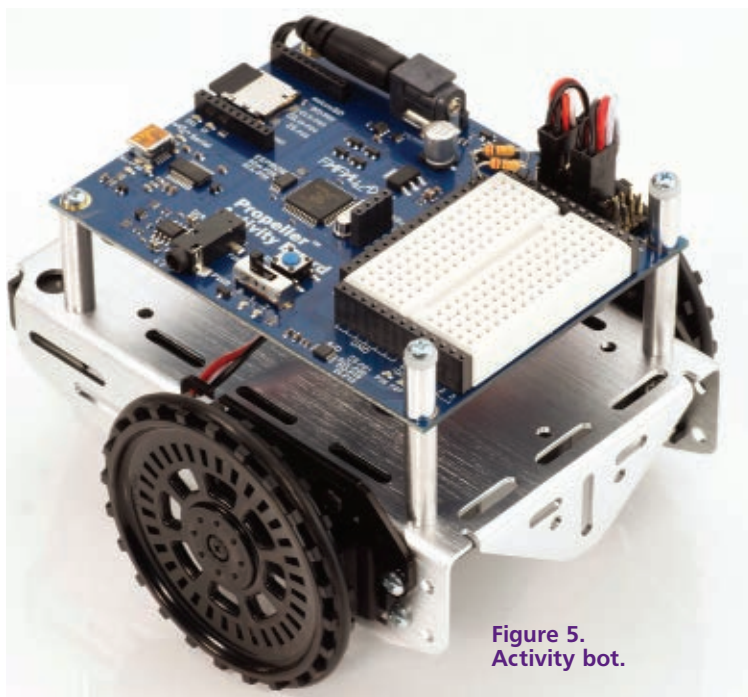


Figure 5. Activity bot.

Parallax is Growing

The Rocklin office employs over 40 full-time people in research and development, sales, manufacturing, education, marketing, and technical support. Parallax has over 100 distributors around the world, including MicroCenter, Mouser, RadioShack, Jameco, Fry's Electronics, and RS Components.

With continued success in the hobby and education markets, Parallax's more recent success in the commercial market has been due to the popularity of the Propeller microcontroller which was first marketed in 2006.

The Propeller is fast becoming the key microcontroller in many of Parallax's in-house products, and also to many other company's products. The HoverFly Technologies controller used in the ELEV quadcopter and other multirotor flyers contains a Propeller at the core.

This device can coordinate inputs from an R/C receiver, gyros, and accelerometers to drive multiple electronic speed controllers in a stable flight mode.

The Propeller 2

The Propeller 2 multicore processor is under development and doesn't have a firm release date as of this writing, though Ken informed me there is a possibility that the first chips would be available in September.

The Propeller 2 processor includes features commonly requested by customers such as code protect, additional RAM, and more I/O pins. The original Propeller has found favor with robot experimenters due to the parallel processing power and I/O capabilities, among its many other features. Beginners like the powerful yet easy language, and Parallax has several different ways of learning about this chip and its capabilities.

The Propeller C Learning System and Activity Board (shown in **Figure 4**) are a good starting point for those interested in the Propeller. At the end of the summer, Parallax will be releasing a new Activity Bot that is great for hobbyists and students, and is shown in **Figure 5**. Parallax also holds several good workshops and conferences, such as the Official Propeller Conference held at their Rocklin offices this past May. Their main website at **Parallax.com** is a good starting point for any information on their products and services, as are the tutorials at **Learn.Parallax.com**.

The Parallax Facilities

Before relating some of my experiences with their products, I would like to give a sense of my feelings of the facility, the employees, and their capabilities. The Rocklin

many other autonomous operations. All of these technologies can be applied to industrial control, autonomous vehicles, aerospace applications, and even appliance and automotive uses.

Parallax has a series of courses that starts from the basics with hands-on projects and programming, and works its way up to more advanced programming, sensor technology, and industrial control. This is a key strategy in their educational development process as it sets the stage for a long-term productive and interactive support system for educators and students alike.

facility is a purpose-built building with a surprising amount of room for expansion. The building (shown in **Figure 6**) is well designed with an inviting entrance and reception area. Typical with many high-tech businesses, the atmosphere amongst the many employees I met gave me the feeling that it was a fun place to work.

When the company president enjoys having a bit of fun showing off on an electric skateboard (**Figure 7**), you can bet that everyone enjoys the work environment.

Product Assembly

For a small electronics manufacturer, the in-house capabilities that Parallax possesses are second to none for a company of this size, in my opinion. Looking at the mechanical side of manufacturing, if a company is building completed robots or robot kits, precision is very important for the components that must fit together.

I have assembled many Parallax kits — from the small Boe-Bots and Stingrays, to the large Eddie and MadeUSA. Holes and slots are precisely positioned so that other components and screws fit perfectly. Though the Boe-Bot sheet metal base is not manufactured in-house, it — along with the mechanical aspects of their other products that are made in Rocklin — are very well built. Nothing is more frustrating than having to bend, tweak, or file holes so different parts will fit together in a kit.

Parallax uses a large Haas SR-100 CNC router (**Figure 8**) to route, mill, and surface many of their large plastic and metal parts for precise fitting. Two Haas CNC super mini milling machines used to produce many aluminum parts are shown in **Figure 9**. A separate standard Acra mill and metal bandsaw shown at the right certainly adds to the flexibility of their machine shop.

Parallax's circuit board production uses the latest in manufacturing technology. Modern SMT integrated circuits are not only a lot smaller than older DIP circuits, but are also harder to place and solder onto a circuit board.

Parallax uses a pick-and-place machine (**Figure 10**) to assemble circuit boards. The selective soldering machine in **Figure 11** is used to solder circuit boards. Hand assembly and testing is also important in any assembly line. **Figure 12** shows the final assembly of the Parallax PropScope — a piece of test equipment that I really like. I've finally stopped using my old Tektronix 475 'boat anchor' in favor of this very useful tool.

Parallax Reaches Out to the Community

Shortly after arriving this past February, Ken met

Figure 8. Parallax building.



Figure 7. Ken Gracey having a bit of fun.

me and took me for a short tour of the facility before we broke for a lunch buffet in the company's lunch room to celebrate several employee's birthdays and another employee's 10 years with the company. After lunch, I was invited to go along with some of the engineering staff to a nearby school to help judge several science fair exhibits.

Figure 8. Haas SR-100 CNC router.

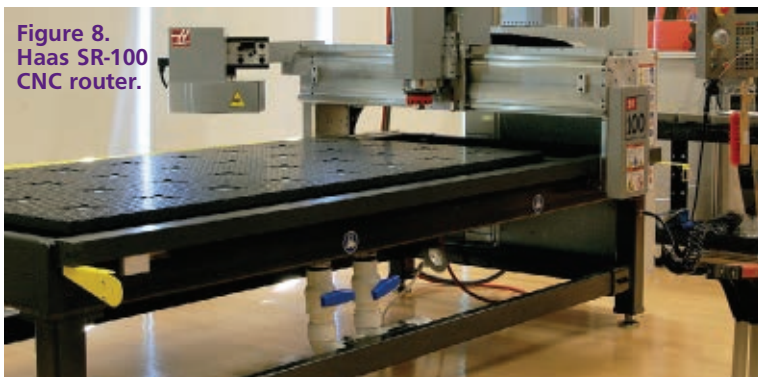




Figure 9. Two Haas CNC super mini milling machines.

Equip Your Genius!

Every successful company has developed a mission for its business venture. They must take into consideration their strengths and weaknesses, as well as the business posture, and develop a strategy to bring a dream to fruition. Most use a short mission statement to describe what they intend to do. The mission statement of Parallax is: *Equip Your Genius!* For robot experimenters, Parallax provides the products, courses, and — most importantly — the service after the sale to equip everyone, from the beginner to robot developers in universities and industry.

Parallax Products for Robot Experimenters

I am not about to list all of the many different products that Parallax makes, but I do want to mention some of the more useful products to robot experimenters. As mentioned, many robot enthusiasts start with the Boe-Bot that now comes with the familiar BASIC Stamp, the Arduino, and the Propeller. Over 400,000 Boe-Bots have been sold. Parallax's S2 (of which 12,000 have been sold) is another great beginner's platform, as well as the larger Stingray which I really like. The advanced Eddie robot that uses the Microsoft Robot Development Studio software has sold almost 300 units, and is one amazing and versatile robot. Parallax also produces a robot platform called the MadeUSA (Made <in> USA) that is the Eddie base system with a series of sensors around the periphery, but no Eddie control board. I have been working with Ken and staff engineer Matt Gilliland to develop a lower cost high-end robot platform based on the original MadeUSA. Hopefully, it will sell for around \$300. It is a very good quality base for experimenters.

Jeff Martin, Parallax Senior Software Engineer, is shown in **Figure 13** with one of the students we judged, Daelin Arney — a tenth grade student at the Western Sierra Collegiate Academy. Arney's pneumatic bladder robotic muscle shown in **Figure 14** was very ingenious.

Ken has also been a mentor to students at his local high school as they designed, assembled, and tested a cataraft (*cat*amaran/*raft*) on the waters of nearby Lake Tahoe — the stunning 192 square mile Alpine mountain lake between California and Nevada. The autonomous/RC raft uses a Propeller microcontroller for control, along with GPS for navigation to assist in the study of the lake. As Ken told me, "We try to turn our preaching into field-tested action, 'else we have no business in education."

This, of course, applies to all of their products and services, as well as their very popular educational series.

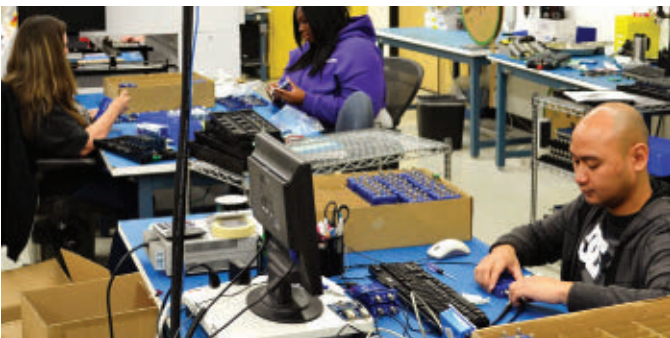


Figure 12. Final assembly of Parallax PropScopes.



Figure 10. Pick-and-place machine.



Figure 11. Protech selective solder machine.

Parallax Ventures into R/C Quadcopters

Of course, it is not all play and no work. Parallax is not just resting on their laurels. Ken, Chip, and their team are always exploring new ways in which to expand their technology into new products. One of the

more exciting 'robots' to be developed at Parallax is the ELEV8 quadcopter shown in **Figure 15**.

Quadcopters — including the ELEV8 — have been discussed in *SERVO* in several articles (including my column), but I am always amazed just how advanced these flyers have become.

The ELEV8 is a bit more than a small foam-surrounded flyer as it can handle a fairly heavy payload of cameras, sensors, and

the like. Parallax has experimented with numerous flyers, from the three boom "Y" hexcopter shown in **Figure 16** to others such as the octocopter shown in **Figure 17**.

During one of my visits to Parallax, Ken and several of his engineering staff and I went to a nearby open field, packing a dozen different flyers and a large box of burgers and fries. Though a lot of 'play' was involved, it is these types of exercises that help Parallax refine and improve the designs.

All of the staff were far more adept at flying than me, but Ken was determined to have me navigate one of the ELEV8s. I had my own transmitter, and binding it to one of his flyers was easy.

My very first flight was pretty good as I managed to

maneuver it around and gently land it on the grass. The second flight was not so graceful as I managed to flip it over just as it came down on the asphalt road. Even crashing upside down, it suffered no damage.

My third flight was even less graceful as I not only tried to land upside down but managed to break several of the props, as shown in **Figure 18**. Ken just politely smiled at me and said "That's okay. No problem."

Parallax Education

When a company produces products as complex as microcontrollers and robots, proper education about the products and their many applications is important for the



Figure 13. Jeff Martin with student Daelin Arney at science fair.



Figure 14. Daelin's ingenious pneumatic robot arm exhibit.

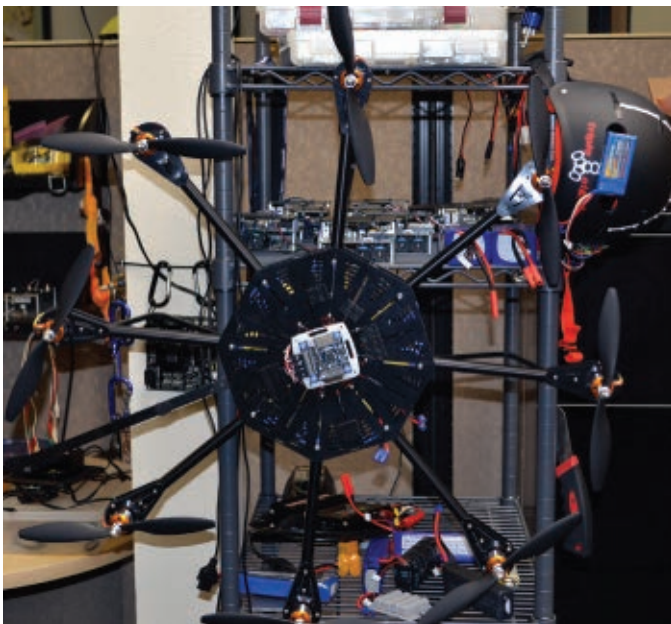


Figure 17. Prototype octocopter hanging on wall.



Figure 15. ELEV8.



Figure 16. ELEV8 hexcopter.



Figure 18. Yes. Props can break if you land upside down on them.

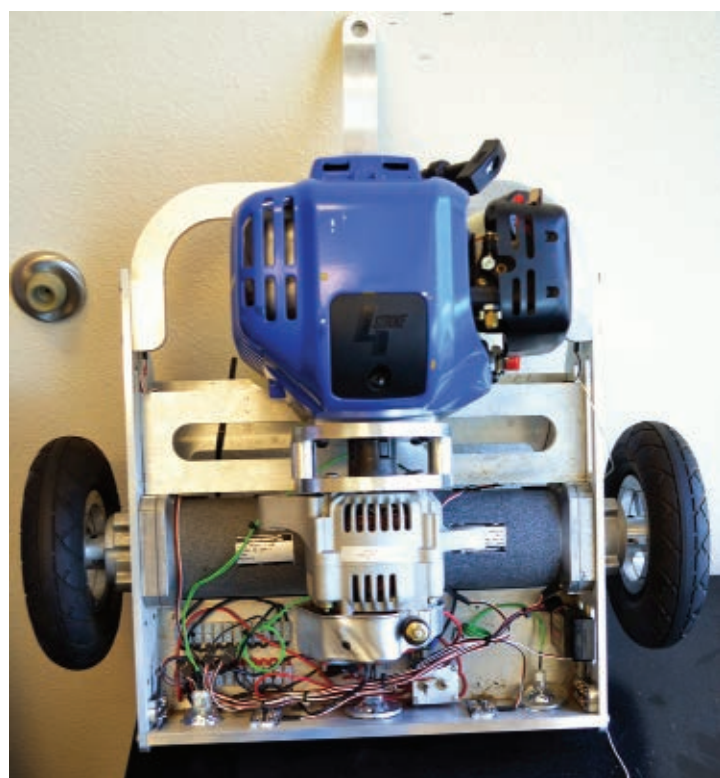


Figure 20. Prototype gas/electric robot.

customer. Jessica Uelmen, Director of Strategic Operations, spent many hours teaching me about the Eddie robot that uses Microsoft's RDS system and its Kinect sensor. It probably took more time for me to learn the system than most people, but using that robot was an amazing experience.

Andy Lindsay (shown in **Figure 19**) is the author of most of the Parallax series of student study guides and was most patient while instructing me on the Propeller-based robot shown in the foreground.

Parallax is also involved with the Boy Scouts, not only in assisting in the preparation of the Scout's robot merit



Figure 19. Andy Lindsay who instructed me in programming.

badge study book, but in instructing BS counselors in how to teach scouts about robots. The company is creating an entire educational line around the Propeller, including a new robot.

Parallax Aims for the Future

Ken showed me a prototype of a gas-engine powered robot base (shown in **Figure 20**) which is similar to their old hydraulic pump/motor QuadRover, but is electrically powered with an alternator electric motor setup. New multi-rotor flyers, Propeller-based robots, an expanded line of educational products, and forever thinking up new products will keep this company in business for years to come.

Their new products notwithstanding, Parallax is also supporting those who prefer the popular Arduino microcontrollers and offer shields to assist with these projects, though they are certainly actively promoting the Propeller for all applications requiring a powerful, yet very affordable microcontroller.

Final Thoughts

My experiences with Parallax products and the friendly staff have left me with some great memories of a good company and nice people who try hard and succeed in producing great products for the robotics, educational, and electronics communities. As previously stated, most of their products are made here in the USA and the quality and customer care is quite evident.

Go online and take a look at their extensive line of products. I'm sure you will be impressed like me. **SV**

ROBO-LINKS



RobotShop.com



Pololu
Robotics & Electronics
WWW.POLOLU.COM

www.canakit.com

- Over 200 Kits & Modules to choose from!
- Easy Worldwide Online Ordering
- Fast Delivery & Same Day Shipping

FM Transmitters • Timers • Audio Amplifiers • Motor Controllers

WHEELS & TIRES

Precision & Off-Road!

low prices
Fast shipping
huge selection
shop now!

Get your project rolling with wheels from ServoCity.com



AndyMark
Inspiring Mobility
www.andymark.com

ALL ELECTRONICS CORPORATION
Electronic Parts & Supplies
Since 1967

Ultrasonic Distance Sensing Made EZ www.maxbotix.com

USB-ProxSonic[®]-EZ™

- Great for kinect applications
- I2C Interface
- Easy Integration
- 1 inch resolution
- Calibrated beam pattern
- Starting at \$49.95

I2CXSL-MaxSonic[®]-EZ™

- Incredible noise immunity
- I2C Interface
- 1cm resolution
- Automatic calibration
- Great for UAV's and robotics
- Starting at \$39.95



Servo Magazine

2009 Volume 7, No. 1-12
2010 Volume 8, No. 1-12
2011 Volume 9, No. 1-12
2012 Volume 10, No. 1-12

Free Shipping!

9 CD-ROMs & Hat Special
Only \$ 189.95
or \$24.95 each.

THE ORIGINAL SINCE 1994

PCB-POOL®
Beta LAYOUT

- Low Cost PCB prototypes
- Free laser SMT stencil with all Proto orders

WWW.PCB-POOL.COM

For the finest in robots, parts, and services, go to
www.servomagazine.com and
click on Robo-Links.

INVEST in your BOT!



HiTEC

12115 Paine Street • Poway, CA 92064 • 858-748-6948 • www.hitecrod.com

ADVERTISER INDEX

All Electronics Corp.	21, 81	HiTec	2, 81	SDP/SI	21
AndyMark	30, 81	Maxbotix	81	Servo City/Robot Zone	7, 81, 83
AP Circuits	49	PanaVise	49	Solutions Cubed	66
Canakit Corp.	35, 81	PCB Pool	65, 81	Univ. for Advancing Technology ..	43
Digilent	Back Cover	Pololu Robotics & Electronics ...	3, 81	Vantec	30
Dongbu Robot Co.	82	Robotis	61	Weirdstuff Warehouse	21
Firgelli	42	RobotShop, Inc	57, 81		

Life with Robot!
Not a dream anymore

HOVIS Series

More than Humanoid!

HOVIS Lite

- > 18 Kinds Of Different Application Models

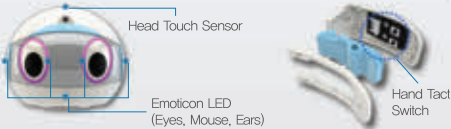


- > 16 Kinds Of Optional Sensor Modules



HOVIS Eco Plus

- > Human Robot Interaction Sensors



Curriculum



HOVIS Genie

Android OS based
Home service robot

HOVIS Eco

20DOF Humanoid with
full body case
and HRI sensors

HOVIS Lite

16DOF Basic Humanoid,
(Upgradeable to HOVIS Eco.)

HerkuleX Series



ARDUINO
ARDUINO Compatible!

- Superior Resolution, Excellent Linearity, Monster Torque
- Compact Design & Easy Assembly System
- Incremental Magneto Resistant Encoder(DRS-0402/0602)

NEW



DRS-0601

NEW



DRS-0602

NEW



DRS-0401

NEW



DRS-0402



DRS-0201



DRS-0101

Size	56mm(W) X 35mm(D) X 46mm(H)		56mm(W) X 35mm(D) X 38mm(H)		45mm(W) X 24mm(D) X 32mm(H)	
Weight	145g		123g		60g	45g
Input Voltage	9.5 ~ 14.8V DC				7 ~ 12V DC	7.4V DC
Stall Torque	7.6N.m (77.0kgf.cm) at 14.8V		5.1N.m (52.0kgf.cm) at 14.8V		2.4N.m (24.0kgf.cm) at 7.4V	1.2N.m (12.0kgf.cm) at 7.4V
Max. Speed	0.164s/60 ° @14.8V		0.162s/60 ° @14.8V		0.147s/60 ° @7.4V	0.166s/60 ° @7.4V
Operating Angle	320 °, Continuous Rotation	720 °, Continuous Rotation (Built-in Speed Controller)	320 °, Continuous Rotation	720 °, Continuous Rotation (Built-in Speed Controller)	320 °, Continuous Rotation	
Resolution	2048 Steps	12960 Steps	2048 Steps	12960 Steps	1024 Steps	
Communication	Full Duplex Asynchronous Serial(TTL), Multi Drop, 0~254 ID, Max 1Mbps (0.67Mbps for DRS-0101, DRS-0201)					
Motor	Premium FAULHABER Coreless DC				Coreless DC	Metal Brush Cored DC
Position Sensor	Potentiometer	Magnetic Encoder	Potentiometer	Magnetic Encoder	Potentiometer	
Gear	Super Reinforced Metal					Engineering Plastic

Dongbu Robot Co., Ltd.

www.dongburobot.com

11th Floor, Bucheon Techno Park 401, Yakdae-dong, Wonmi-gu, Bucheon-city, Gyeonggi-do 420-734, Korea
TEL : +82-32-329-5551(ext.311), FAX : +82-32-329-5569, E-MAIL : robotsales@dongbu.com



Dongbu Robot

SERVOCITY

We have the parts for your ideas!

ARM YOURSELF WITH THE PARTS FOR SUCCESS!

Actobotics' unique overlapping hole patterns allow for virtually unlimited mounting possibilities.

Shop Online | Call 620.221.0123 | sales@servocity.com

Our Servo Gearboxes give your project extra power

Huge selection of tubing & shafting

Digital & Programmable

SERVOblocks
BY ROBOTZONE

Perfect for wrist and joint mechanisms

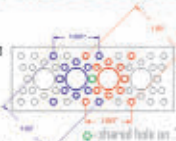
HUNDREDS OF NEW COMPONENTS ONLINE AND GROWING DAILY

**Ball-bearing based parts offer
tight tolerances and low friction**

-- Learn more about Actobotics™ --

Overlapping hole patterns offer extreme versatility when designing and building structures.

32P metal gears



Brand New!

Actobotics
BALL-BEARING PRECISION BUILDING SYSTEM

**DREAM.
DESIGN.
BUILD.
REPEAT.**

...and much more!

Channel & Brackets

Hub Mounts

Bearing Mounts

Gears & Sprockets

Shafting & Tubing

Hubs & Adaptors

Wheels & Tires



WORLDWIDE
SHIPPING!

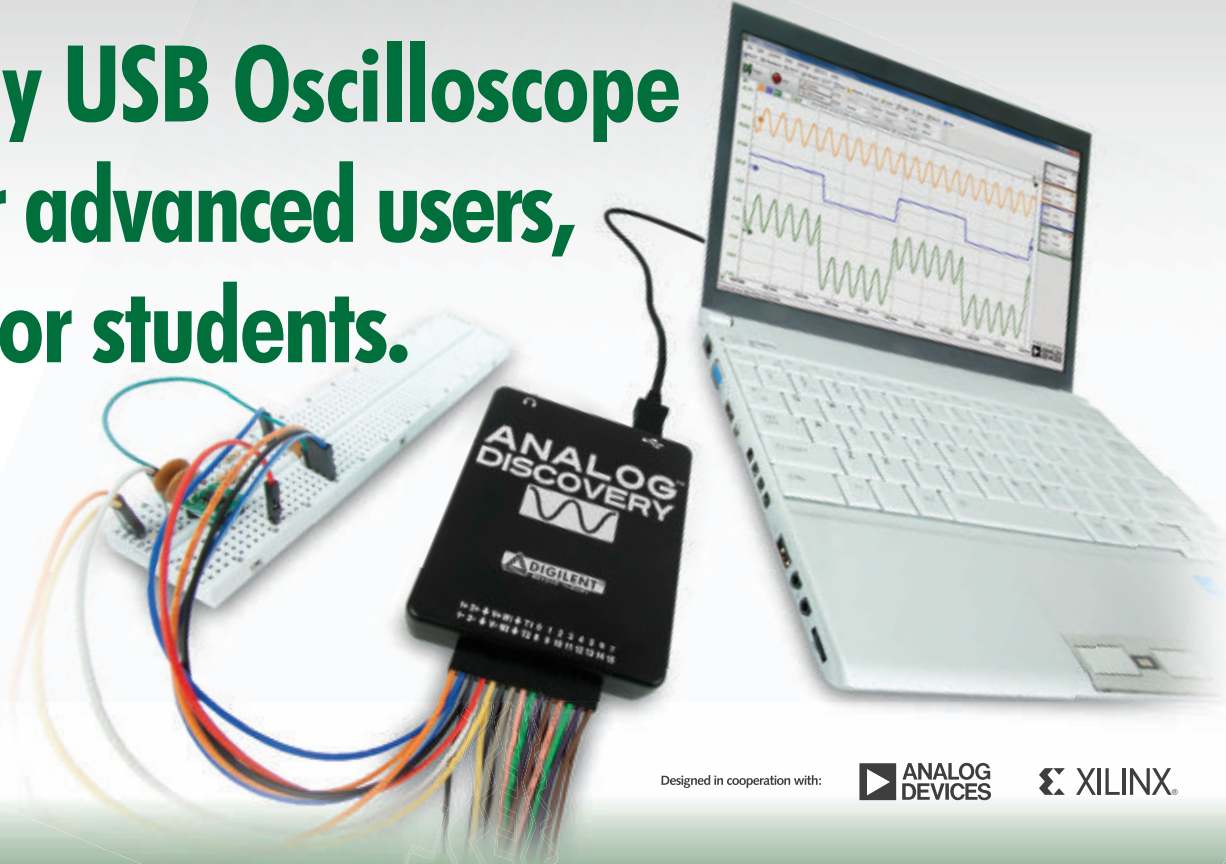
www.SERVOCITY.com

JOIN OUR ONLINE COMMUNITY!



The only USB Oscilloscope built for advanced users, priced for students.

\$99.00
(U.S. student price)



Designed in cooperation with:



Turn any PC into a powerful electrical engineering workstation! The USB-powered Analog Discovery lets you measure, visualize, analyze, record and control mixed signal circuits of all kinds. It's small enough to fit in your pocket, but powerful enough to replace a stack of lab equipment. Driven by the free WaveForms™ software, the Analog Discovery lets you build and test analog and digital circuits in virtually any environment, in or out of the lab.

- 2-Channel Oscilloscope
- 2-Channel Waveform Generator
- 16-Channel Logic Analyzer
- 16-Channel Digital Pattern Generator
- $\pm 5\text{VDC}$ Power Supplies
- Spectrum Analyzer
- Network Analyzer
- Voltmeter
- Digital I/O

Now supported by MATLAB / MATLAB student edition

Also Available:

Analog Parts Kit (APK)

- 20+ ICs from Analog Devices
- 200+ discrete components
- Solderless breadboard
- Perfect for Circuits 1&2 classes

\$69.99

Discovery BNC Adapter

- Allows the use of standard BNC-terminated probes
- Selectable AC & DC coupling

\$19.99



www.digilentinc.com/AnalogDiscovery

